CONVERSIONS AND CONSTANTS

NUMERICAL PREFIXES

PREFIX	SYMBOL	EXPONENT
EXA	E	10^{18}
PETA	P	10^{15}
TERA	T	10^{12}
GIGA	G	10^{9}
MEGA	M	10^{6}
KILO	k	10^{3}
HECTO	h	10^{2}
DECA	da	10
DECI	d	10^{-1}
CENTI	c	10^{-2}
MILLI	m	10^{-3}
MICRO	M	10^{-6}
NANO	n	10^{-9}
PICO	p	10^{-12}
FEMTO	f	10^{-15}
ATTO	a	10^{-18}

VOLUME

1 QUART = 2 PINTS
1 US. GALLON = 3.785 LITERS
= 4 QUARTS
1 BRIT. GALLON = 277.42 in^3
1 ft^3 = 7.48 US. GALLONS
1 BARREL (bbl) = 42 GALLONS
1 GANTA = 3 LITERS
= 8 CHUPAS
1 CAVAN = 25 GANTAS

MASS

1 TONNE = 1 METRIC TON
= 1000 kg
1 SHORT TON = 2000 lbsm
1 LONG TON = 2240 lbsm
1 kg = 2.21 lbs
1 lbs = 16 oz.
1 SLUG = 32.2 lbsm

DENSITY / CONCENTRATION

1 kg/L = 62.4 lb/ft^3
1 ppm = 1 mg/L
= 1 mg/kg

FORCE

1 N = 100,000 DYNES
1 kgf = 9.81 N
1 lbf = 4.448 N

DISTANCE, SPEED, ACCEL.

1 STATUTE MILE = 5280 ft.
1 NAUTICAL MILE = 6080 ft.
1 LEAGUE = 3 NAUTICAL MILES
1 YARD = 3 FEET
1 METER = 3.281 FT.
1 FOOT = 12 INCHES
1 INCH = 2.54 cm.
1 ROD = 5.5 YARDS
1 FURLONG = 220 YARDS
1 CABLE LENGTH = 720 FT.
1 FATHOM = 6 ft.
1 CHAIN = 66 ft.
1 FURLONG = 660 ft.
1 SPAN = 9 INCHES

1 LIGHT YEAR = 9.46×10^{12} m
1 KNOT = 1 NAUT. MILE/hr.
1 m/s = 3.6 kph
9.81 m/s^2 = 32.2 ft/s^2

AREA

1 ACRE = 1 FURLONG × 1 CHAIN
= 660 ft × 66 ft
1 ARE = 100 m^2
1 HECTARE = 10,000 m^2

ANGLES

1 REV = 2π RAD = 360°
= 400 GRAD = 400 GONS
= 6400 MILS

PRESSURE

1 atm = 101.325 kPa
= 14.7 psi
= 760 mmHg
= 29.92 inHg
= 1.032 kg/cm^2
= 760 torr
1 bar = 100 kPa

ENERGY

1 BTU = 778 ft-lb
= 252 cal
= 1055 J
1 kcal = 4.187 kJ
1 JOULE = 10^7 erg
1 erg = 1 DYNE − cm
1 CENTIGRADE HEAT UNIT (CHU) = 1.8 BTU
1 ev = 1.602×10^{-19} J

POWER

1 hp = 0.746 kW
= 550 lb-ft/s
= 33000 lb ft/min
= 2545 BTU/hr
= 42.4 BTU/min
= 1.014 Mhp
1 BOILER hp = 35,322 kJ/hr
1 TOR = 3.516 kW
= 12000 BTU/hr
1 METRIC hp (Mhp) = 0.736 kW

TEMPERATURE

$°F = 1.8C + 32$
$°C = \frac{(F-32)}{1.8}$
$R = °F + 460$
$K = °C + 273$

$\Delta T_F = 1.8\Delta T_C$
$\Delta T_K = \Delta T_C$
$\Delta T_R = \Delta T_F$
$1°Re = \frac{4}{5}°C$
$1°Re = 20°L$

VISCOSITY

ABSOLUTE	KINEMATIC
1 REYN = 1 $\frac{lb\text{-}sec}{in^2}$	1 STOKE = 1 $\frac{cm^2}{s}$

1 POISE = 1 $\frac{DYNE\text{-}s}{cm^2}$
= 0.1 Pa-s

CONSTANTS

GAS LAWS

$\bar{R} = 8.3143 \frac{J}{mol \cdot K}$
$= 1545 \frac{lbf\text{-}ft}{lbm \cdot mol \cdot R}$
$= 0.0821 \frac{L\text{-}atm}{mol\text{-}K}$

GENERAL

$g = 9.81\ m/s^2$
$N_A = 6.022 \times 10^{23}\ mol^{-1}$
$\sigma = 5.67 \times 10^{-8} \frac{W}{m^2 K^4}$
$C = 3 \times 10^8 \frac{m}{s}$
SOLAR CONSTANT = $1353 \frac{W}{m^2}$
PLANCK'S C. (h) = 6.626×10^{-34} J·S
GRAVITATIONAL C. (G) = $6.664 \times 10^{11} \frac{Nm^2}{kg}$
RADIUS OF EARTH = 6.38×10^6 m
VEL. TO ESCAPE EARTH = 11.2 km/s
HUMAN HEAT = 225 BTU/hr

PROPERTIES OF AIR / GASES

$C_p = 1 \frac{kJ}{kgK} = 0.24 \frac{BTU}{lbR}$
$C_v = 0.7186 \frac{kJ}{kgK} = 0.1714 \frac{BTU}{lbR}$
$R = 0.287 \frac{kJ}{kgK} = 53.34 \frac{lb\text{-}ft}{lb\ °R}$
k = 1.4
= 1.3 (HOT)
$\rho = 1.2\ kg/m^3$
$= 0.075 \frac{lb}{ft^3}$

MOL. WTS.
H = 1
He = 4
C = 12
N = 14
O = 16
S = 32
AIR = 28.97

K OF GASES

He, NOBLE GASES	1.667
CARBON DIOXIDE CO_2	1.287
NITROGEN, N_2	1.399

PROPERTIES OF H_2O / LIQUIDS

$C_{p_W} = 4.187 \frac{kJ}{kg\,K} = 1.0 \frac{BTU}{lbR}$
$C_{p\,ice} = 2.093 \frac{kJ}{kg\,K} = 0.5 \frac{BTU}{lb\,R}$

LATENT HEATS:

ICE: L_f = 334 kJ/kg = 144 BTU/lb
WATER: L_v = 2257 kJ/kg = 970 BTU/lb

SURFACE TENSION:
@ 0°C = 0.076 N/m
@ 100°C = 0.059 N/m

SG:
$SG_{Hg} = 13.6$
$SG_{sea} = 1.03$

STEEL

$E = 30 \times 10^6$ psi = 210 GPa
$G = 12 \times 10^6$ psi = 83 GPa
$\alpha = 11.7 \times 10^{-6}/°C = 6.5 \times 10^{-6}/°F$
$\rho = 7850 \frac{kg}{m^3} = 490 \frac{lb}{ft^3}$

HEAT TRANSFER

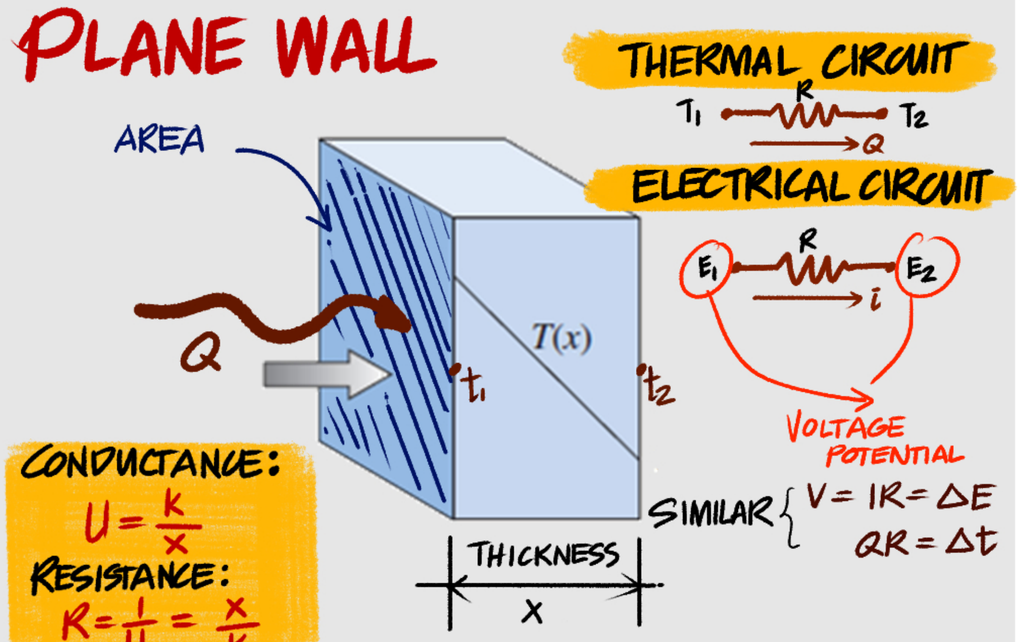
MODES OF HEAT TRANSFER

TYPE	DEFINITION
CONDUCTION	BODIES IN CONTACT. MOLECULAR COMMUNICATION THROUGH SOLID MATERIALS OR STAGNANT FLUIDS
CONVECTION	MXING AND MOTION OF PARTICLES OF A SUBSTANCE.
RADIATION	ELECTROMAGNETIC WAVES ARE PASSED FROM ONE BODY TO ANOTHER THROUGH A SPACE

CONDUCTION

CONDUCTION THROUGH WALL

PLANE WALL



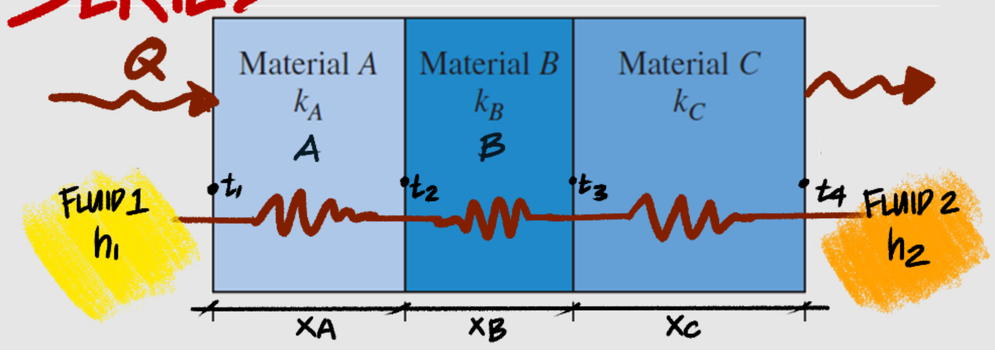
CONDUCTANCE: $U = \frac{k}{x}$

RESISTANCE: $R = \frac{1}{U} = \frac{x}{K}$

$$Q = \frac{\Delta t}{R} = \frac{\Delta t}{\left(\frac{x}{KA}\right)}$$

$$R = \frac{x}{kA}$$

SERIES

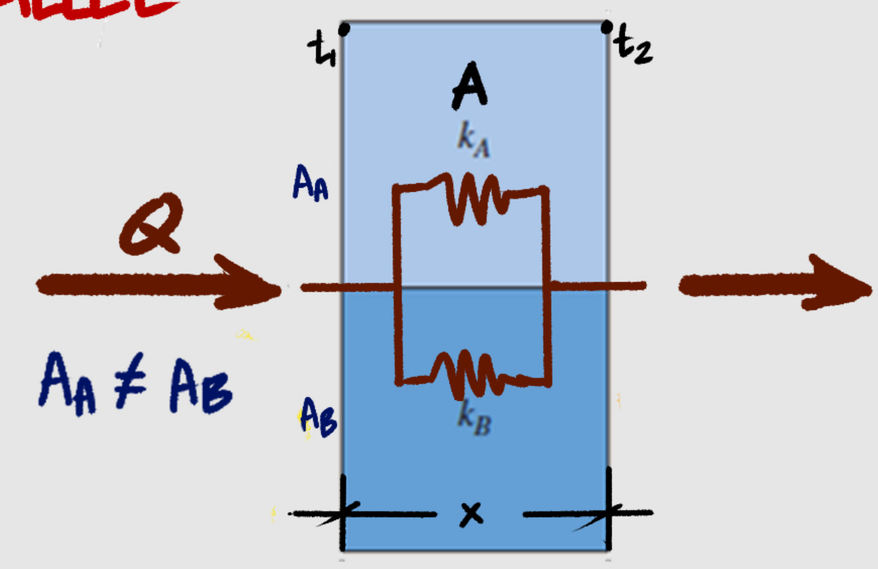


$$Q = \frac{\Delta t}{\frac{1}{h_1 A} + \frac{x_A}{k_A A} + \frac{x_B}{k_B A} + \frac{x_C}{k_C A} + \frac{1}{h_2 A}}$$

IF WITH CONVECTION

$$R_T = R_A + R_B + R_C \ldots$$

PARALLEL



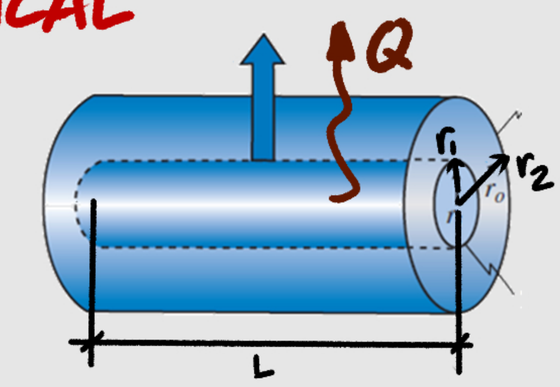
$$Q = \frac{\Delta t}{\left[\left(\frac{x}{k_1 A_1}\right)^{-1} + \left(\frac{x}{k_2 A_2}\right)^{-1}\right]^{-1}}$$

$$Q = \frac{\Delta t\,(k_1 A_1 + k_2 A_2)}{x}$$

$$R_{TOT} = \left[R_1^{-1} + R_2^{-1} \ldots + R_n^{-1}\right]^{-1}$$

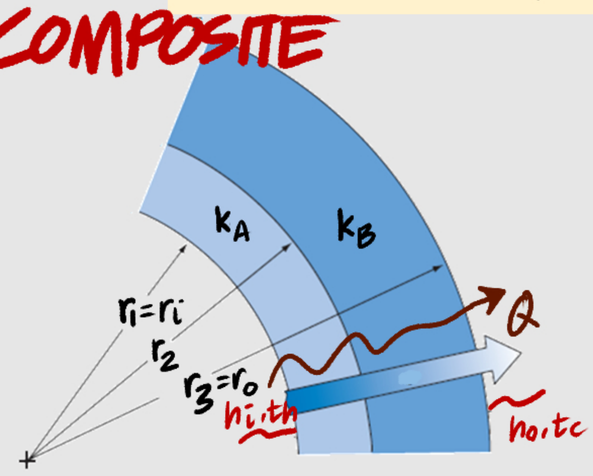
CONDUCTION THROUGH PIPE

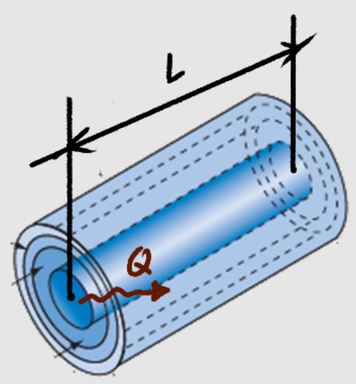
CYLINDRICAL WALL



$$Q = \frac{\Delta t}{\left(\frac{\ln\left(\frac{r_2}{r_1}\right)}{2\pi k L}\right)} \qquad R = \frac{\ln\left(\frac{r_2}{r_1}\right)}{2\pi K_1 L}$$

COMPOSITE





$$Q = \frac{\Delta t}{\frac{1}{h_i(2\pi r_i L)} + \left(\frac{\ln\left(\frac{r_2}{r_1}\right)}{k_A(2\pi L)}\right) + \left(\frac{\ln\left(\frac{r_3}{r_2}\right)}{k_B(2\pi L)}\right) + \frac{1}{h_o(2\pi r_o L)}}$$

$A = 2\pi r L$

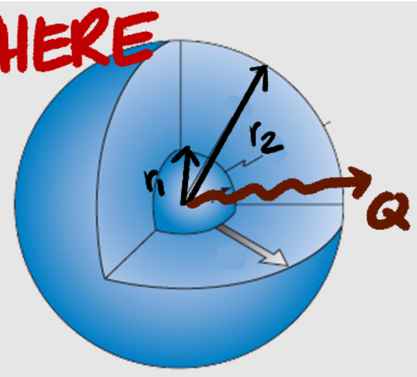
CONVERSION:

$$1\ \frac{BTU}{hr \cdot ft \cdot {}^\circ F} = 1.73\ \frac{W}{mK}$$

CONDUCTION THROUGH SPHERE

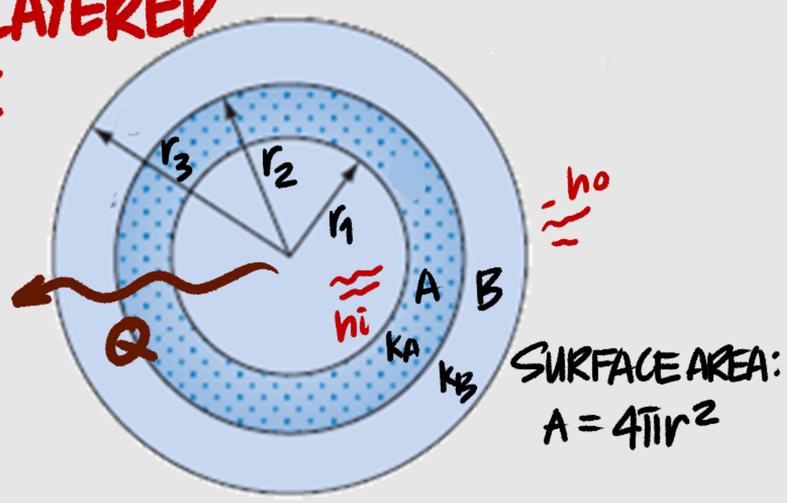
HOLLOW SPHERE

$$R = \frac{r_2 - r_1}{(4\pi r_2 r_1)k}$$



$$Q = \frac{\Delta t}{\frac{r_2 - r_1}{(4\pi r_2 r_1)(k)}}$$

MULTI-LAYERED SPHERE



SURFACE AREA:
$A = 4\pi r^2$

$$Q = \frac{\Delta t}{\frac{1}{h_1 A_1} + \frac{r_2 - r_1}{4\pi r_2 r_1 k_A} + \frac{r_3 - r_2}{4\pi r_3 r_2 k_B} + \frac{1}{h_2 A_2}}$$

THERMAL DIFFUSIVITY

DEFINES THE SPEED OF HEAT PROPAGATION BY CONDUCTION DURING CHANGES OF TEMPERATURE. THE HIGHER THE THERMAL DIFFUSIVITY, THE FASTER THE HEAT PROPAGATION.

$$\alpha = \frac{k}{\rho c_p}$$

k = THERMAL COND.
ρ = DENSITY
c_p = SPECIFIC HEAT

R-VALUE

MEASURE OF INSULATOR'S ABILITY TO REDUCE THE RATE OF FLOW

$$R\text{-VALUE} = \frac{\text{THICKNESS}}{\text{EFF. AVE. THERM. CONDUCTIVITY}}$$

μ_d = DYNAMIC VISCOSITY	D = DIAMETER
c_p = SPECIFIC HEAT	ρ = DENSITY
h = HEAT TRANSFER COEF.	β = COEF. THERM. EXPANSION
k = THERMAL CONDUCTIVITY	g = GRAVITATIONAL ACCEL.

CONVECTION

FREE CONVECTION

- HEAT IS TRANSFERRED DUE TO THE MIXING AND MOTION OF PARTICLES OF A SUBSTANCE

FORCED CONVECTION

- MOVEMENT BECAUSE OF A MECHANICAL POWER

$$Q = hA\Delta t$$

h = FILM COEFFICIENT ; $\frac{W}{m^2K}$

$$1\ \frac{BTU}{hr\text{-}ft^2\text{-}°F} = 5.765\ \frac{W}{m^2K}$$

CRITICAL RADIUS

USED FOR SMALL DIAMETER SYSTEMS

FOR CYLINDERS	FOR SPHERES
$\dot{r} = k/h$	$\dot{r} = 2k/h$

BIOT NUMBER

IF THE BIOT NUMBER IS VERY SMALL, THEN THE CONDUCTION RESISTANCE IS NEGLIGIBLE COMPARED TO THE CONVECTION RESISTANCE

$$Bi = \frac{\text{RESISTANCE TO CONDUCTION}}{\text{RESISTANCE TO CONVECTION}}$$

$$Bi = \frac{(x/kA)}{(1/hA)} = \frac{hx}{k}$$

"X or L"
X = THICKNESS
L = CHAR. LENGTH
$L = \frac{\text{VOL.}}{\text{AREA}}$

REYNOLD'S NUMBER

$$N_{RE} = \frac{\rho V D}{\mu d} = \frac{VD}{MK}$$

PRANDTL NUMBER (FORCED & FREE CONVECTION)

DIMENSIONLESS PARAMETER REPRESENTING THE RATIO OF DIFFUSION OF MOMENTUM TO DIFFUSION OF HEAT IN A FLUID

$$N_{PR} = \frac{\mu d c_p}{k}$$

NUSSELT NUMBER (FORCED CONVECTION)

RATIO OF HEAT CONVECTION TO HEAT CONDUCTION

$$N_{NU} = \frac{hL}{k}$$

GRASHOF NUMBER (FREE CONVECTION)

NONDIMENSIONAL PARAMETER USED IN THE CORRELATION OF HEAT AND MASS TRANSFER DUE TO THERMALLY INDUCED NATURAL CONVECTION AT A SOLID SURFACE IMMERSED IN A FLUID

$$N_{GR} = \frac{D^3 \rho^2 \beta g \Delta T}{\mu d^2}$$

RADIATION

STEFAN-BOLTZMANN LAW $E \propto T^4$

ANYTHING WHOSE TEMPERATURE IS ABOVE THE SURROUNDING WILL ALWAYS RADIATE A SIGNIFICANT AMOUNT OF HEAT

$$Q = e\sigma A(T_1^4 - T_2^4)$$

$\sigma = 5.67 \times 10^{-8}$ W/m²K⁴

$\sigma = 0.1714 \times 10^{-8}$ BTU/hr.ft².R⁴

$a + r + t = 1$

- TRANSMISSIVITY
- REFLECTIVITY
- ABSORPTIVITY

$c = \lambda f$ — FREQUENCY, WAVELENGTH

$\therefore mc^2 = hf$

$E = mc^2$

$E = hf$

PLANCK'S CONSTANT: 6.625×10^{-34} J·s

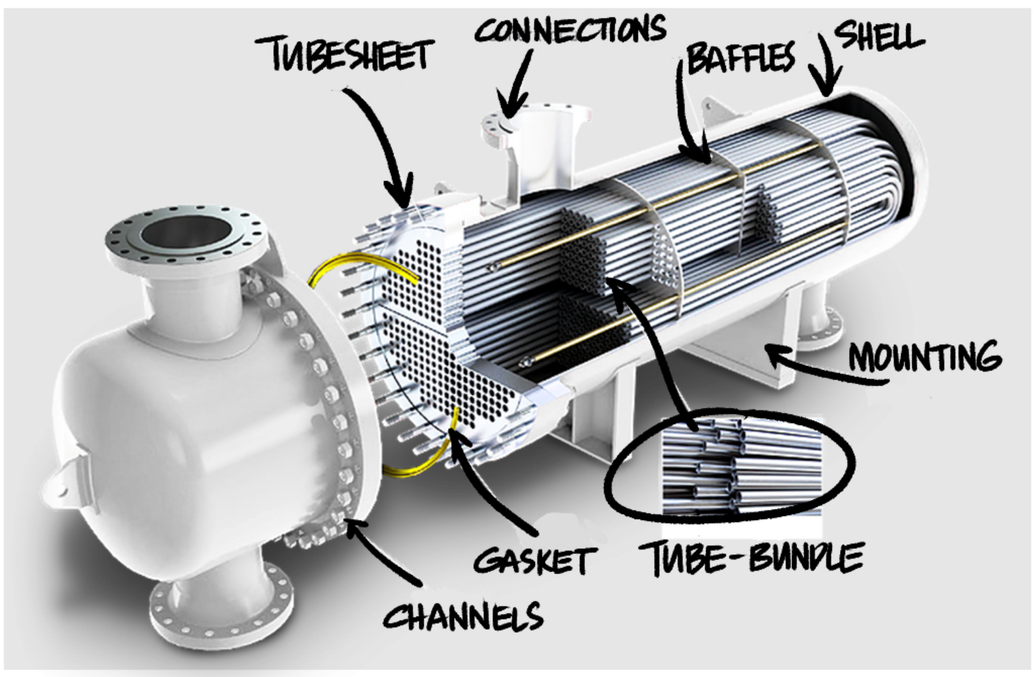
$mc = \frac{hf}{c}$ = MOMENTUM

- **PLANCK'S LAW**
  - ALL SUBSTANCES EMIT RADIATION WHICH DEPENDS UPON THE ABSOLUTE TEMPERATURE AND MATERIAL
- **KIRCHHOFF'S LAW**
  - REFERS TO WAVELENGTH-SPECIFIC RADIATIVE EMISSION AND ABSORPTION BY A MATERIAL BODY IN THERMODYNAMIC EQUILIBRIUM, INCLUDING RADIATIVE EXCHANGE EQUILIBRIUM.

$$\frac{\text{TOTAL EMISSIVE POWER}}{\text{ABSORPTIVITY}} = K$$

- **EMISSIVITY**
  - THE RATIO OF RADIATION FROM AN ACTUAL BODY TO THE RADIATION FROM A BLACK BODY
- **BLACK BODY**
  - IDEALIZED SURFACE THAT EMITS RADIATION AT THE MAXIMUM RATE
- **GRAY BODY**
  - ACTUAL BODY THAT RADIATES LESS HEAT THAN A BLACK BODY

HEAT EXCHANGER



HEAT EXCHANGERS

- ANY DEVICE WHICH AFFECTS THE TRANSFER OF HEAT FROM ONE SUBSTANCE TO ANOTHER

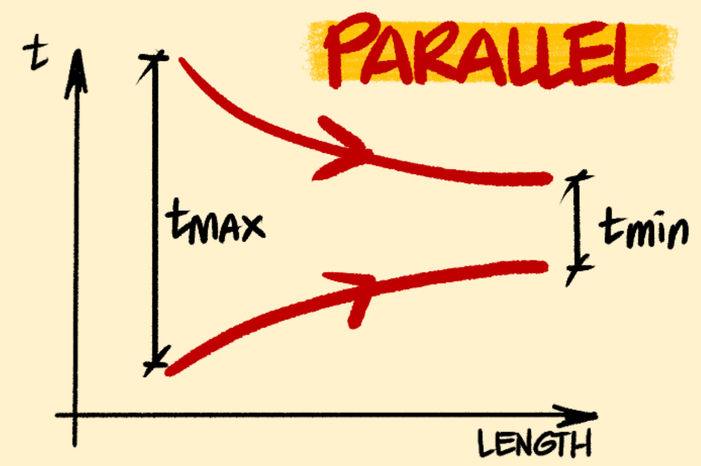
LOGARITHMIC MEAN TEMP. DIFFERENCE

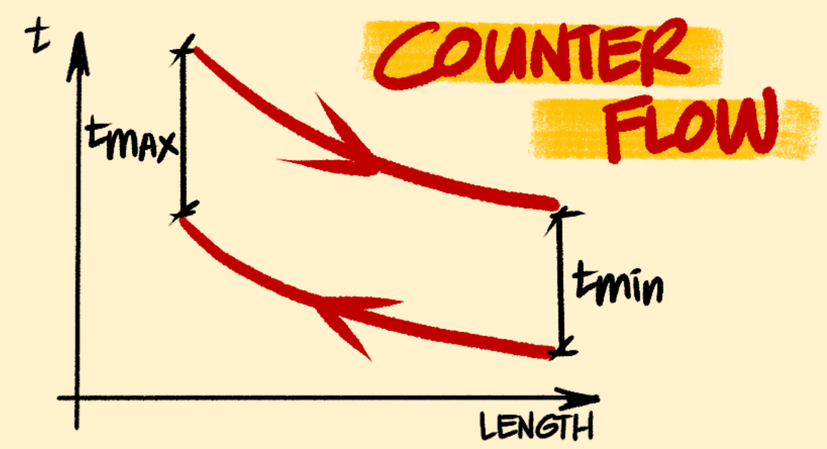
$$LMTD = \frac{\Delta t_{max} - \Delta t_{min}}{\ln(\Delta t_{max} / \Delta t_{min})}$$

ARITHMETIC MEAN TEMP. DIFFERENCE

$$AMTD = \frac{\Delta t_{max} + \Delta t_{min}}{2}$$

PARALLEL VS. COUNTER FLOW



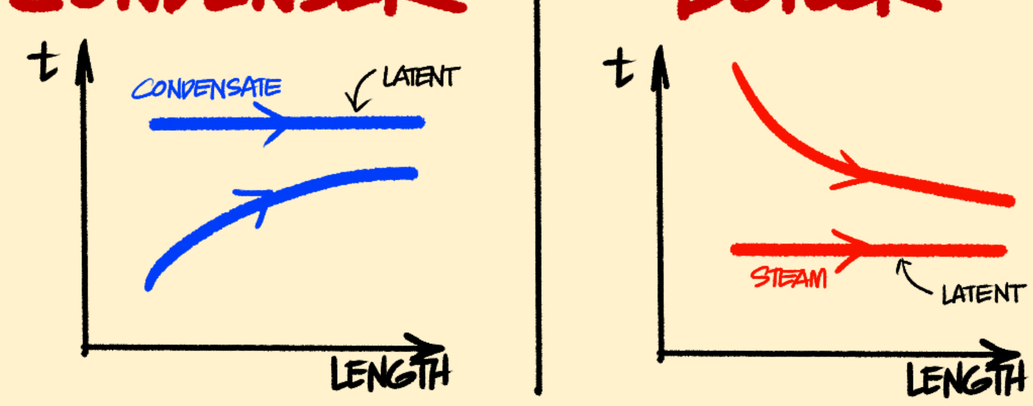


STEAM CONDENSER

- FLUID AT CONSTANT TEMPERATURE GIVES UP HEAT TO A COLDER FLUID, THE FLUID'S TEMP. GRADUALLY INCREASES

STEAM BOILER

- FLUID AT CONSTANT TEMPERATURE RECEIVES HEAT FROM A WARMER FLUID (TEMPERATURE IS DECREASING)



HEAT TRANSFER

$$Q = U_o A_T (LMTD)$$

HEAT TRANSFER AREA

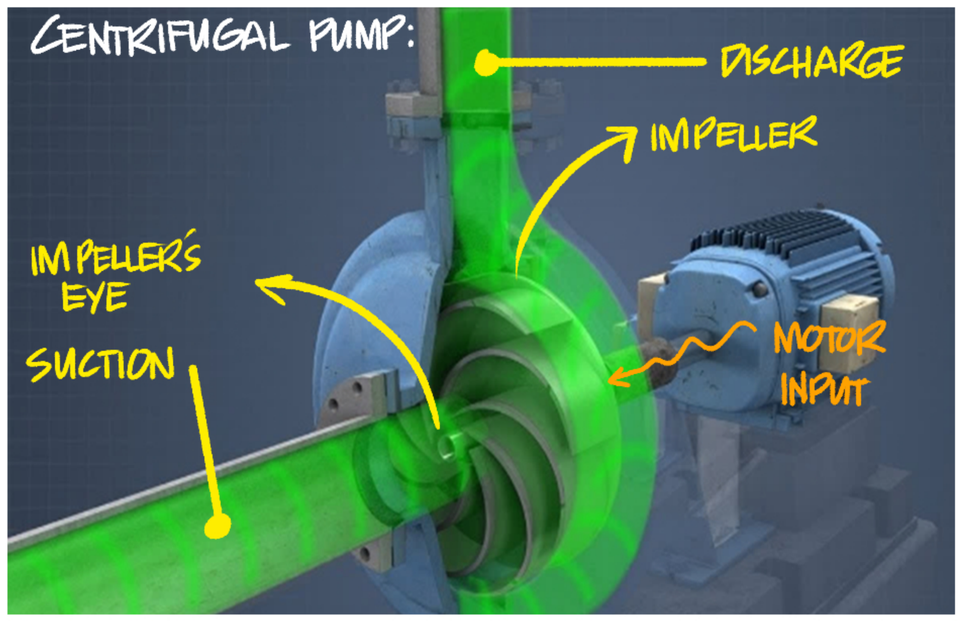
$$A_T = \pi d_o L \left(\frac{\text{NO. OF TUBES}}{\text{PASS}}\right)(N_{\text{PASSES}})$$

VOLUME FLOW RATE

$$\text{VOLUME FLOWRATE} = \frac{\pi}{4} d_i^2 \left(\frac{\text{NO. OF TUBES}}{\text{PASS}}\right) \cdot V$$

PUMPS

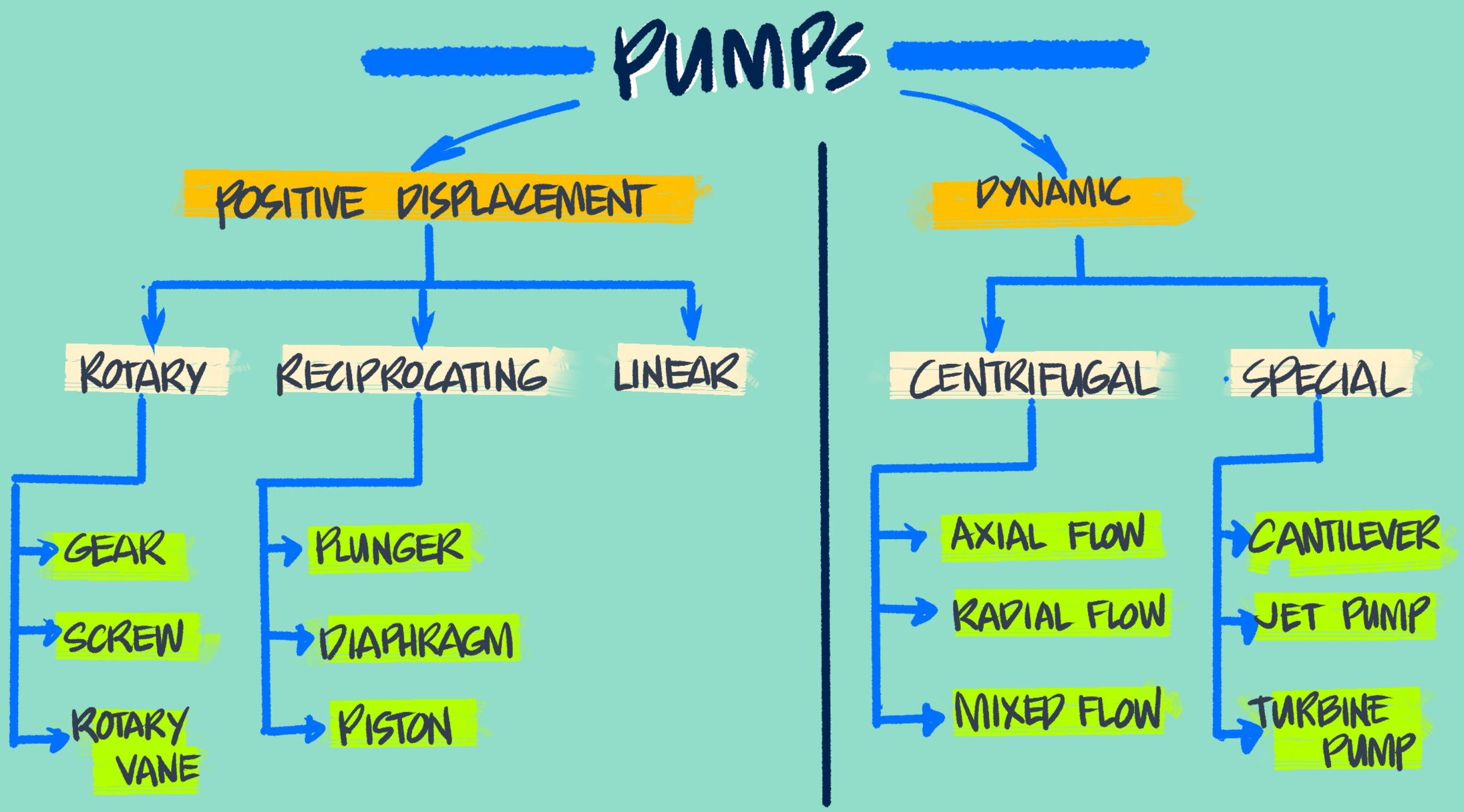
THE PURPOSE OF A PUMP IS TO **TRANSFER** A FLUID **FROM A REGION OF LOW PRESSURE** TO ANOTHER REGION AT THE **SAME OR HIGHER PRESSURE.**



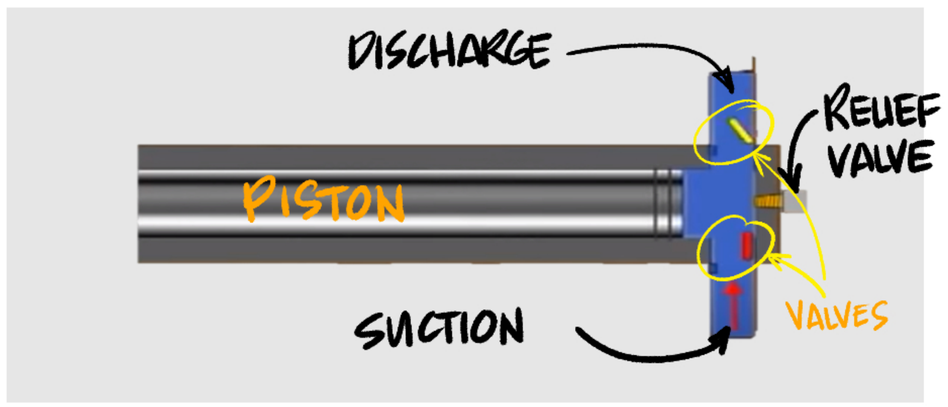
POSITIVE DISPLACEMENT VS. DYNAMIC ??

- **POSITIVE DISPLACEMENT**
  - IMPELLERS **PASS ON VELOCITY** FROM THE MOTOR **TO THE LIQUID** WHICH MOVES THE FLUID TO THE DISCHARGE PORT
  - **PRODUCES FLOW BY CREATING PRESSURE**
- **DYNAMIC (KINETIC)**
  - **TRAPS CONFINED AMOUNTS OF LIQUID** AND FORCES IT FROM THE SUCTION TO THE DISCHARGE PORT
  - **PRODUCES PRESSURE BY CREATING FLOW**

TYPES OF PUMPS



RECIPROCATING PUMPS

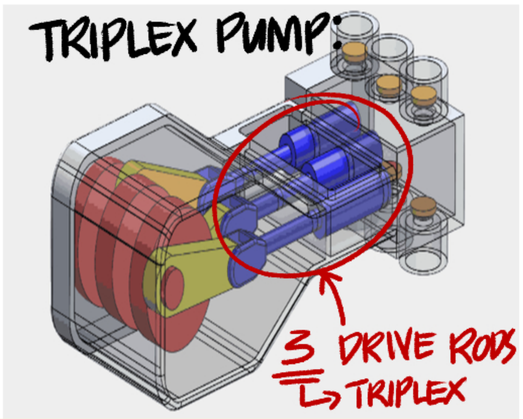


DISCHARGE	LOW
HEAD	HIGH
SPEED	LOW
SELF-PRIMING	

USES A PISTON AND CYLINDER ARRANGEMENT WITH SUCTION AND DISCHARGE VALVES INTEGRATED INTO THE PUMP.

ADDITIONAL INFORMATION:

- COMMONLY USED AS **BOILER FEED PUMP** FOR STEAM
- CAN BE DOUBLE ACTING OR SINGLE ACTING
- CAN SIMPLEX, DUPLEX, TRIPLEX
- **AIR CHAMBER** – USED TO SMOOTHEN THE FLOW DUE TO THE NATURE OF FLOW OF LIQUID. THIS IS PLACED EITHER ON THE SUCTION SIDE OR DISCHARGE SIDE.
- IN NEW PUMPS, SLIPPAGE IS WITHIN **2%.**



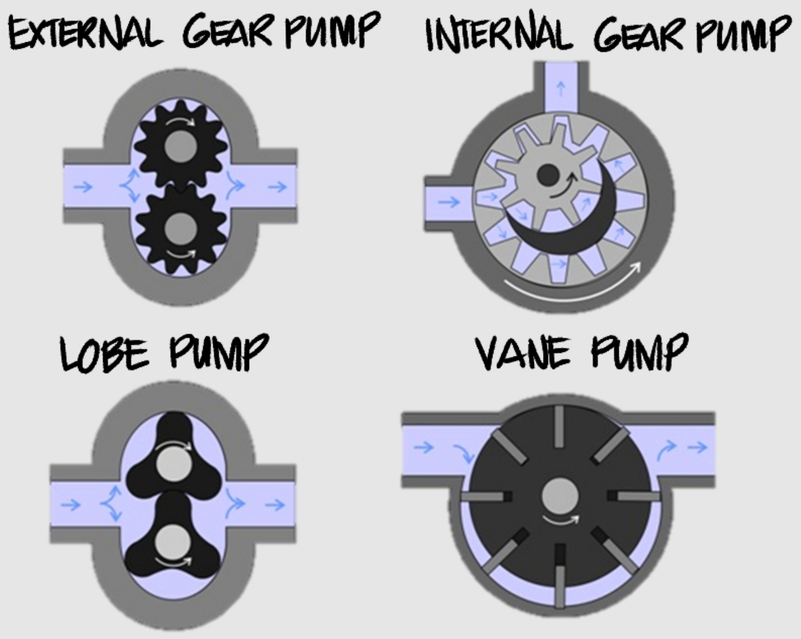
SIMPLEX, DUPLEX, TRIPLEX??

A RECIPROCATING PUMP DESIGN THAT UTILIZES (N) SEPARATE DRIVE RODS TO DRIVE THE PUMPS PLUNGERS OR PISTONS.

DUPLEX – 2

TRIPLEX – 3

ROTARY PUMPS



GEAR PUMP

- IT MOVES A FLUID BY REPEATEDLY ENCLOSING A FIXED VOLUME USING INTERLOCKING COGS OR GEARS, TRANSFERRING IT MECHANICALLY USING A CYCLIC PUMPING ACTION.

VANE PUMP

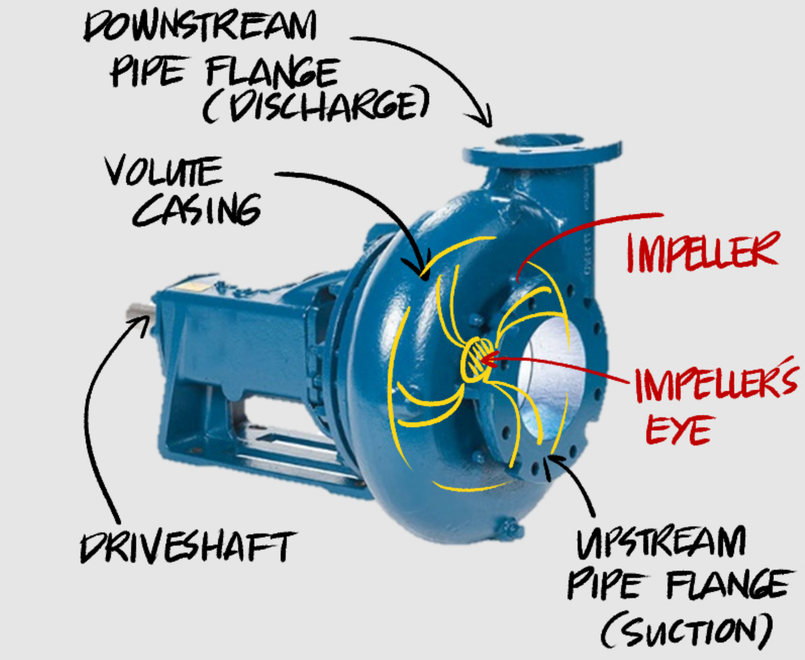
- A POSITIVE-DISPLACEMENT PUMP THAT CONSISTS OF VANES MOUNTED TO A ROTOR THAT ROTATES INSIDE A CAVITY. IN SOME CASES THESE VANES CAN HAVE VARIABLE LENGTH AND/OR BE TENSIONED TO MAINTAIN CONTACT WITH THE WALLS AS THE PUMP ROTATES

DISCHARGE	LOW
HEAD	LOW

APPLICATION:
VISCOUS FLUIDS (OIL)

OTHER TYPES:
- SCREWS
- CAM AND PISTON
- SHUTTLE BLOCK TYPE

CENTRIFUGAL PUMPS



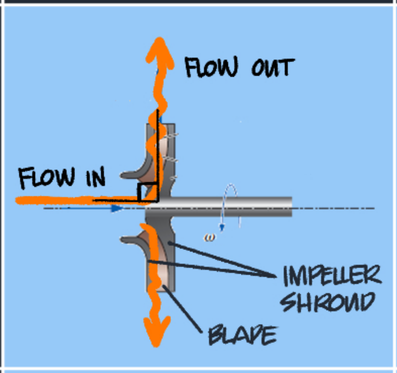
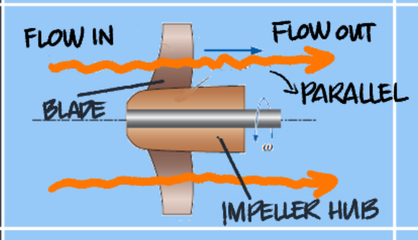
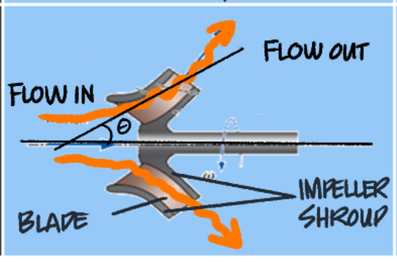
- A PUMP IN WHICH THE PRESSURE IS DEVELOPED PRINCIPALLY BY THE ACTION OF **CENTRIFUGAL FORCE.**
- CONVERT KINETIC ENERGY INTO PRESSURE ENERGY THROUGH **DIFFUSER VANES**

DISCHARGE	HIGH
HEAD	LOW
SPEED	HIGH
NOT SELF-PRIMING	

IMPELLERS:
- HIGHER HEADS – LOW SPECIFIC SPEEDS
- LOWER HEADS – HIGH SPECIFIC SPEEDS

SPECIFIC SPEED ??

IN RPM, IMPELLER WOULD OPERATE TO GIVE **1 GPM** FOR A **TOTAL DYNAMIC HEAD OF 1 FOOT**.

DIRECTION OF FLOW	FIGURE	DESCRIPTION	PRESSURE	DISCHARGE
RADIAL		- DISCHARGED RADIALLY (OR TANGENTIALLY) ALONG THE OUTER RADIUS OF THE PUMP CASING - **90 DEGREES TURN TO OUTWARD**	HIGH	LOW
AXIAL		- FLUID ENTERS AND LEAVES AXIALLY - **PARALLEL**	LOW	HIGH
MIXED		- INTERMEDIATE BETWEEN CENTRIFUGAL AND AXIAL - **SOME ANGLE BETWEEN RADIALLY AND AXIALLY.**	RELATIVELY HIGH	RELATIVELY HIGH

DOUBLE SUCTION PUMPS ??
- EMPLOYED WHEN THE **FLOW RATE REQUIRED BECOMES TOO LARGE** FOR THE INLET CROSS-SECTIONS OF ONE IMPELLER
- WHEN THE FLOW VELOCITY OF THE FIRST IMPELLER HAS TO BE **REDUCED TO PREVENT CAVITATION.**

WHAT TO DO?

WHEN GIVEN **DOUBLE SUCTION PUMPS**, DIVIDE GIVE CAPACITY (VOLUME FLOW RATE) BY **2**.

DEEP WELL PUMPS

TURBINE PUMPS

- PUMPS FOR HIGH SUCTION LIFT UP TO **305 M.**

PLUNGER PUMPS

- MODIFICATION OF THE OLD HAND. THIS IS BEST SUITED WHERE THE **LIFTS IS 7.6 M OR OVER** AND **CAPACITIES UP TO 190 LITERS PER MINUTE.**

EJECTOR – CENTRIFUGAL PUMPS

- COMBINES A SINGLE –STAGE CENTRIFUGAL PUMP AT THE TOP OF THE WELL AND AN EJECTOR/JET LOCATED DOWN IN THE WATER
- USED FOR SMALL CAPACITIES

AIR LIFTS

- COMPRESSED AIR BEING ADMITTED TO THE WELL TO LIFT THE WATER TO THE SURFACE

CLASSIFICATION OF PUMPS BASED ON SUCTION LIFT	
SHALLOW WELL PUMP	UP TO 25 FT.
DEEP WELL PUMP	UP TO 120 FT.
TURBINE PUMP	UP TO 300 FT.
SUBMERSIBLE	FOR HIGH HEAD

CAVITATION

- IS THE SPONTANEOUS VAPORIZATION OF THE FLUID, RESULTING IN A **DEGRADATION OF PUMP PERFORMANCE.**
- THE FORMATION OF CAVITIES OF WATER VAPOR IN THE SUCTION SIDE OF A PUMP DUE TO LOW PRESSURE

NPSH AVAILABLE > NSPSH REQUIRED

$$NPSH = \pm H_s + H_p - H_f$$

$H_s \rightarrow$ STATIC LEVEL
+ ABOVE
− BELOW
> CENTERLINE

$H_p \rightarrow$ ABSOLUTE PRESSURE ON THE LIQUID SURFACE OF PUMP SUCTION SUPPLY

$H_f \rightarrow$ TOTAL FRICTION HEAD LOSS IN SUCTION

CAUSES OF CAVIATION	PREVENTING CAVITATION
1. DISCHARGE HEAD FAR BELOW THE PUMP HEAD AT PEAK EFFICIENCY	1. INCREASE HE HEIGHT OF THE FLUID SURFACE
2. HIGH SUCTION LIFT	2. REDUCE FRICTION AND MINOR LOSSES BY **SHORTENING THE SUCTION LINE OR USING LARGER PIPE SIZE**
3. LOW SUCTION HEAD	3. REDUCE FLUID TEMPERATURE AT FLUID ENTRANCE
4. EXCESSIVE PUMP SPEED	4. PRESSURIZING THE FLUID SUPPLY TANK
5. HIGH LIQUID TEMPERATURE	5. REDUCING THE FLOW RATE OR VELOCITY

NPSH (NET POSITIVE SUCTION HEAD)

– DIFFERENCE BETWEEN ACTUAL SUCTION PRESSURE AND SATURATION VAPOR PRESSURE

PUMP HEADS

FRICTION HEAD
- THE HEAD REQUIRED TO OVERCOME THE RESISTANCE TO FLOW IN THE PIPE AND FITTINGS.

STATIC HEAD
- IS THE HEIGHT OF THE SURFACE OF WATER ABOVE THE GAUGE POINT.

PRESSURE HEAD
- IS THE STATIC HEAD PLUS GAUGE PRESSURE ON THE WATER SURFACE PLUS FRICTION HEAD.

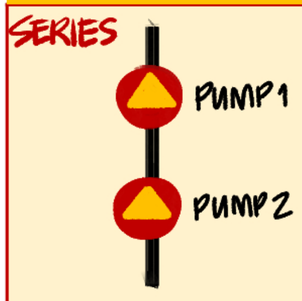
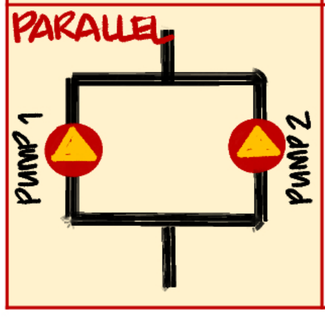
VELOCITY HEAD
- IS THE HEAD REQUIRED TO PRODUCE A FLOW OF THE WATER.

SUCTION LIFT
- THE VERTICAL DISTANCE FROM THE LIQUID SUPPLY LEVEL TO THE PUMP CENTER LINE WITH **THE PUMP PHYSICALLY LOCATED ABOVE THE LIQUID LEVEL SUPPLY.**

SUCTION HEAD
- THE VERTICAL DISTANCE FROM THE LIQUID SUPPLY LEVEL TO THE PUMP CENTER LINE WITH **THE PUMP PHYSICALLY LOCATED BELOW THE LIQUID LEVEL SUPPLY.**

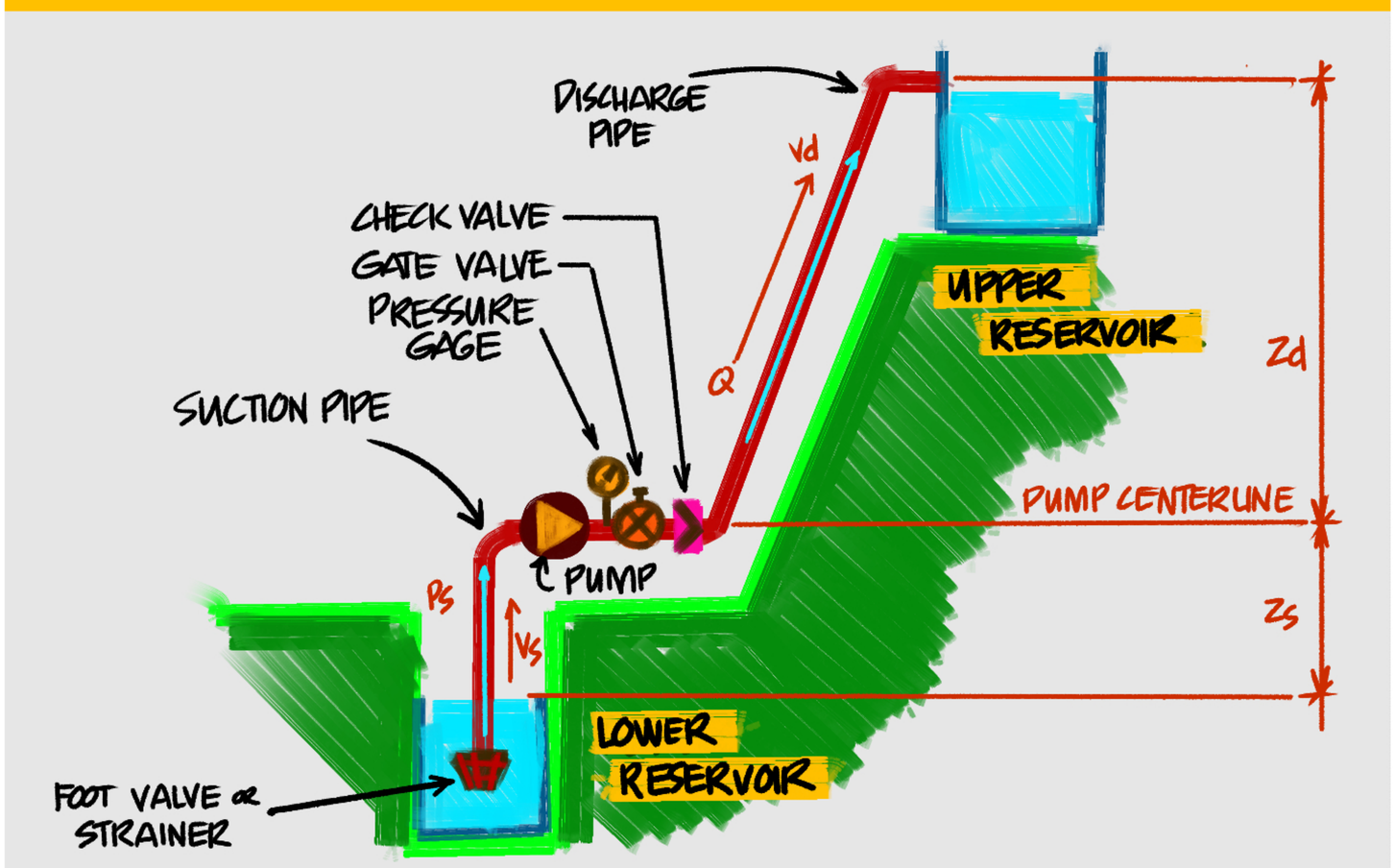
STATIC DISCHARGE HEAD
- THE VERTICAL DISTANCE IN **BETWEEN THE PUMP CENTER LINE AND THE POINT OF FREE DISCHARGE** ON THE SURFACE OF THE LIQUID IN THE DISCHARGE TANK.

PUMPS IN SERIES/PARALLEL

	OBJECTIVE	HEAD	VOLUME FR
SERIES 	INCREASE HEAD	$h_1 + h_2 + \dots$	$Q_1 = Q_2$
PARALLEL 	INCREASE DISCHARGE/ VOLUME FLOW	$h_1 = h_2$	$Q_1 + Q_2 + \dots$

OTHER INFORMATION	
END SUCTION PUMP	SUCTION NOZZLE ON THE **OPPOSITE SIDE OF THE CASING** FROM THE STUFFING BOX AND THE FACE OF THE SUCTION NOZZLE PERPENDICULAR TO THE LONGITUDINAL AXIS OF THE SHAFT.
IN LINE PUMP	A CENTRIFUGAL PUMP WHOSE DRIVE UNIT IS SUPPORTED BY THE PUMP HAVING ITS **SUCTION AND DISCHARGE FLANGES ON APPROXIMATELY THE SAME CENTER.**
HORIZONTAL PUMP	SHAFT NORMALLY IN A HORIZONTAL POSITION
VERTICAL SHAFT TURBINE PUMP	HAS **ONE OR MORE IMPELLERS DISCHARGING INTO ONE OR MORE BOWLS** AND A VERTICAL COLUMN PIPE USED TO CONNECT THE BOWLS TO THE DISCHARGE HEAD ON WHICH THE PUMP DRIVER IS MOUNTED.
HORIZONTAL SPLIT-CASE PUMP	CHARACTERIZED BY A HOUSING WHICH IS **SPLIT PARALLEL TO THE SHAFT**
BOOSTER PUMP	TAKES SUCTION FROM A PUBLIC OR PRIVATE WATER SYSTEM FOR THE **PURPOSE OF INCREASING THE EFFECTIVE WATER PRESSURE.**
SUBMERSIBLE PUMP	A **VERTICAL TURBINE PUMP** WITH PUMP AND MOTOR CLOSED COUPLED AND **INSTALLED UNDERGROUND**
STATIC WATER LEVEL	THE LEVEL, WITH RESPECT TO THE PUMP, OF OF WATER FROM WHICH IT TAKES SUCTION WHEN THE **PUMP IS NOT IN OPERATION**
PUMPING WATER LEVEL	THE LEVEL, WITH RESPECT TO THE PUMP, OF WATER FROM WHICH IT TAKES SUCTION WHEN **THE PUMP IS IN OPERATION.**
DRAW-DOWN	DIFFERENCE BETWEEN THE **PUMPING WATER LEVEL AND THE STATIC WATER LEVEL**

TYPICAL PUMP INSTALLATION



VOLUME FLOW RATE

$$Q = \text{AREA} \times \text{VELOCITY}$$

TOTAL HEAD / TOTAL DYNAMIC HEAD (TDH)

$$TDH = (Zd - Zs) + \left(\frac{Pd - Ps}{\gamma}\right) + \left(\frac{Vd^2 - Vs^2}{2g}\right) + \Sigma hf$$

ELEVATION HEAD · PRESSURE HEAD · VELOCITY HEAD · FRICTION LOSS (SUCTION & DISCHARGE)

PUMP EFFICIENCY

PUMP WORK: $P_w = \gamma Q h$

$$W_{Pb} = \frac{W_p}{e}$$

W_{Pb} → BRAKE WORK

CHARACTERISTICS OF CENTRIFUGAL PUMPS

SPECIFIC SPEED

$$N_s = \frac{N\sqrt{Q}}{h^{3/4}} \qquad \frac{51.65\,N\sqrt{Q}}{h^{3/4}} \;\Big|\; Q = m^3/s,\ h = m \quad (SI)$$

N = SPEED, rpm
Q = DISCHARGE, GPM
h = HEAD, ft

SIMILAR PUMPS

$$\frac{N_1\sqrt{Q_1}}{h_1^{3/4}} = \frac{N_2\sqrt{Q_2}}{h_2^{3/4}} \qquad \frac{Q_1}{N_1 D_1^3} = \frac{Q_2}{N_2 D_2^3}$$

Q	H	P	
1	2	3	N
1	2	3	D

NOTE: COMBINE FORMULA BELOW, IF NONE IS CONSTANT.

SAME PUMPS

A. CONSTANT DIAMETER VARIABLE SPEED

$$\frac{Q_1}{Q_2} = \left(\frac{N_1}{N_2}\right)^1 \qquad \frac{h_1}{h_2} = \left(\frac{N_1}{N_2}\right)^2 \qquad \frac{P_1}{P_2} = \left(\frac{N_1}{N_2}\right)^3$$

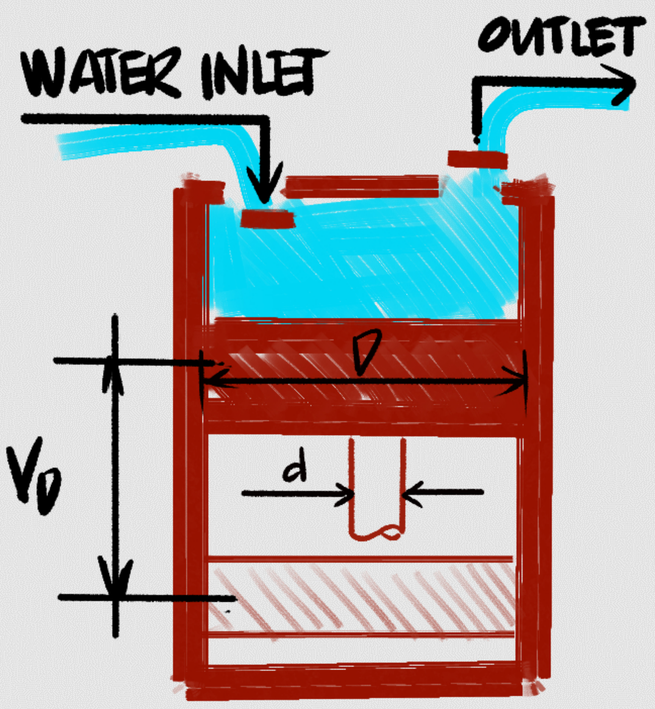
B. CONSTANT SPEED VARIABLE DIAMETER

$$\frac{Q_1}{Q_2} = \left(\frac{D_1}{D_2}\right)^1 \qquad \frac{h_1}{h_2} = \left(\frac{D_1}{D_2}\right)^2 \qquad \frac{P_1}{P_2} = \left(\frac{D_1}{D_2}\right)^3$$

C. CONSTANT SPEED VARIABLE DENSITY

$$\frac{Q_1}{Q_2} = \frac{\rho_1}{\rho_2} \qquad \frac{h_1}{h_2} = \frac{\rho_1}{\rho_2} \qquad \frac{P_1}{P_2} = \frac{\rho_1}{\rho_2}$$

CHARACTERISTICS OF RECIPROCATING PUMPS



RECIPROCATING PUMP

PISTON DISPLACEMENT

☑ ROD NEGLECTED

$$V_D = 2\left(\frac{\pi}{4}\right)(D^2)\,LN$$

☑ ROD CONSIDERED

$$V_D = \frac{\pi}{4}(D^2)\,LN + \frac{\pi}{4}(D^2 - d^2)\,LN$$

SLIP

$$SLIP = V_D - Q$$

PERCENT SLIP (% SLIP)

$$\%\,SLIP = \frac{V_D - Q}{V_D} \times 100\%$$

VOLUMETRIC EFFICIENCY

$$e_V = \frac{Q}{V_D}$$

$$e_V = 1 - \%\,SLIP$$

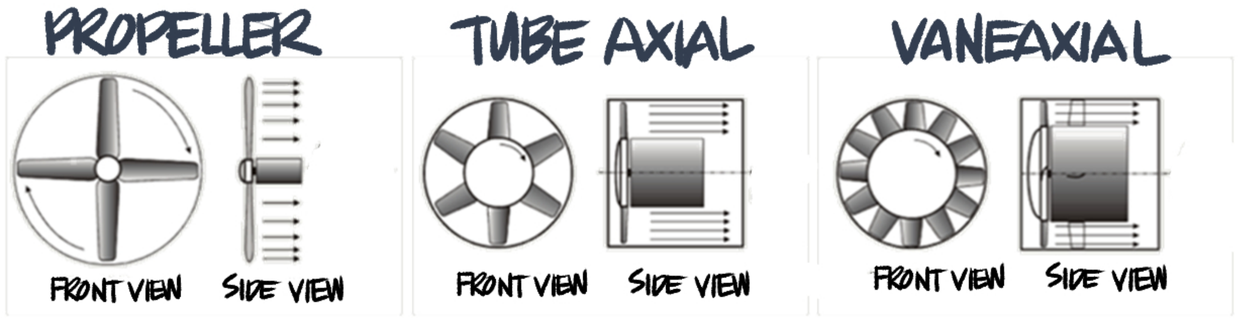
FANS AND BLOWERS

- **FAN**
  - APPLY POWER TO A GAS TO INCREASE ITS ENERGY CONTENT THEREBY CAUSING IT TO FLOW OR MOVE.
- **BLOWER**
  - A FAN USED TO FORCE AIR UNDER PRESSURE WHICH MEANS RESISTANCE TO GAS FLOW IS IMPOSED UPON DISCHARGE.
- **EXHAUSTER**
  - A FAN USED TO WITHDRAW AIR UNDER PRESSURE WHICH MEANS RESISTANCE TO GAS FLOW IS IMPOSED UPON SUCTION

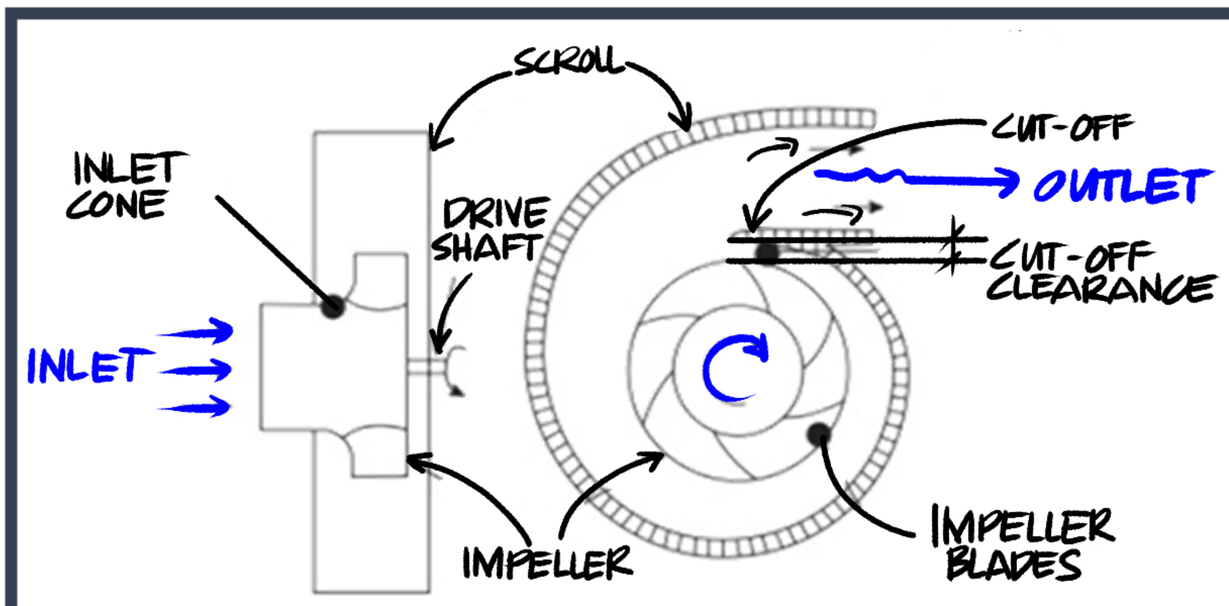
BASIC DIFFERENCES ACCORDING TO ASME

FANS	PRESSURE RISE EQUAL TO OR BELOW **1 PSIG.**
BLOWERS	PRESSURE RISE BETWEEN **1 – 50 PSIG.**
COMPRESSORS	PRESSURE RISE **ABOVE 50 PSIG.**

AXIAL FANS



CENTRIFUGAL FANS



FAN LAWS

A. FAN SPEED VARIATION

$$\frac{Q_2}{Q_1} = \left(\frac{N_2}{N_1}\right) \quad \frac{h_2}{h_1} = \left(\frac{N_2}{N_1}\right)^2 \quad \frac{P_2}{P_1} = \left(\frac{N_2}{N_1}\right)^3$$

B. FAN SIZE VARIATION

$$\frac{Q_2}{Q_1} = \left(\frac{D_2}{D_1}\right)^3 \quad \frac{h_2}{h_1} = \left(\frac{D_2}{D_1}\right)^2 \quad \frac{P_2}{P_1} = \left(\frac{D_2}{D_1}\right)^5$$

Q	h	P	SHORTCUT!!
1	2	3	N
3	2	5	D
0	1	1	P

FANS IN SERIES/PARALLEL

SERIES	$Q_1 = Q_2$	$h_{TOT} = h_1 + h_2$
PARALLEL	$Q_{TOT} = Q_1 + Q_2$	$h_1 = h_2$

STATIC HEAD

$$P_{WATER} = P_{AIR}$$
$$\gamma_w h_w = \gamma_a h_a$$
$$h_s = \frac{\gamma_w h_w}{\gamma_a}$$

DENSITY OF AIR @ 1 atm; 21.1°C $= 1.2 \frac{kg}{m^3} = 0.075 \frac{lb}{ft^3}$

VELOCITY HEAD

$$h_v = \frac{V_o^2}{2g}$$

h_v = METERS OF AIR
V_o = OUTLET VELOCITY

TOTAL HEAD

$$h = h_s + h_v$$

CAPACITY OF FAN

$$Q = A_o \times V_o$$

POWER OUTPUT OF A FAN/ AIR POWER

$$P_{AIR} = \gamma_{AIR} Q \times h = \rho_{air} \times g \times h$$

STATIC AIR POWER

$$P_{STATIC\ AIR} = \rho_{AIR} \times g \times h_s$$

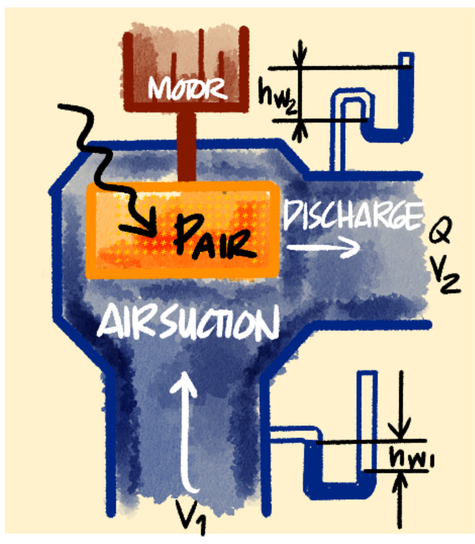
STATIC FAN EFFICIENCY

$$e_s = \frac{\text{STATIC AIR POWER}}{\text{SHAFT POWER}} = \frac{P_{STAT.\ AIR}}{P_b}$$

MECHANICAL EFFICIENCY

$$e_m = \frac{\text{AIR POWER}}{\text{SHAFT POWER}} = \frac{P_{AIR}}{P_b}$$

BERNOULLI'S EQUATION FOR FAN



$$h = \frac{P_2 - P_1}{\gamma} + \frac{V_2^2 - V_1^2}{2g}$$

SINCE $P = \gamma h_s$

$$h_s = \frac{\rho_w h_w}{\rho_{AIR}}$$

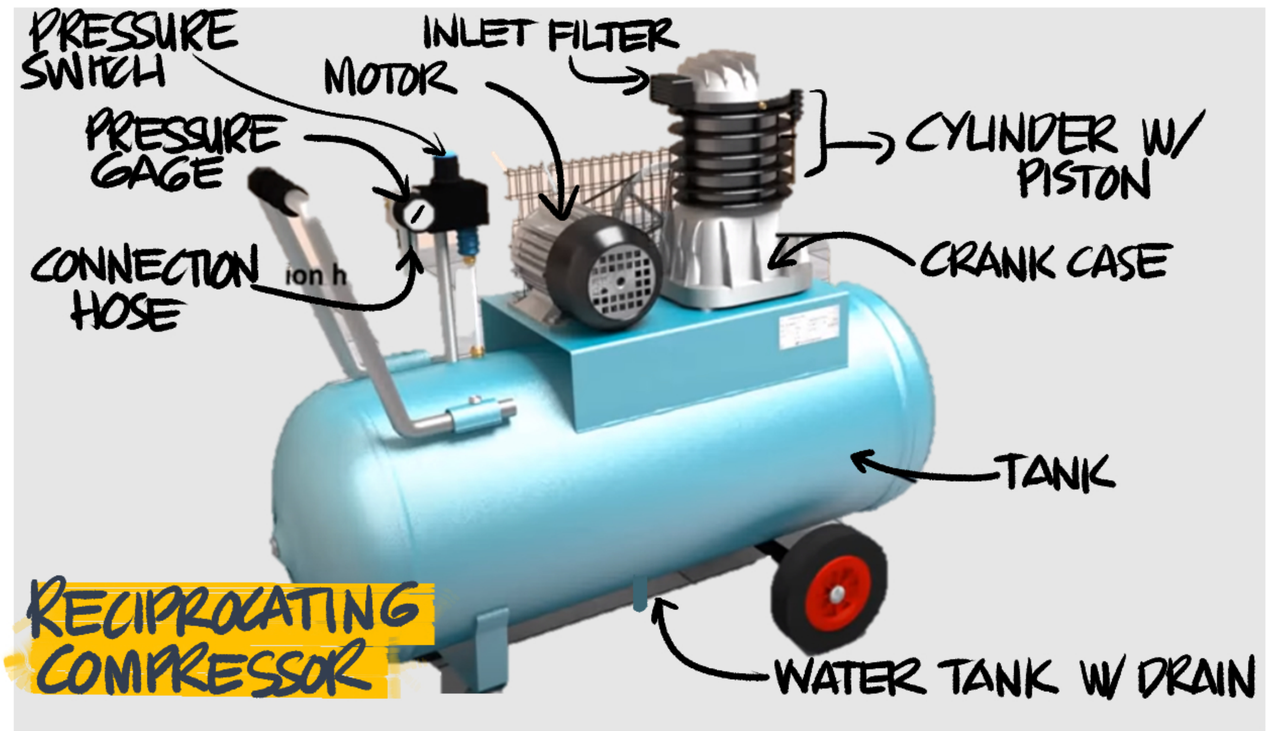
$$h = \frac{(h_{w2} - h_{w1})\rho_w}{\rho_{AIR}} + \frac{V_2^2 - V_1^2}{2g}$$

COMPRESSORS

IS A MACHINE USED TO INCREASE THE PRESSURE OF AIR (OR GAS) BY DECREASING ITS VOLUME.

COMPRESSORS VS. PUMPS???

- COMPRESSORS ARE SIMILAR TO PUMPS, BOTH INCREASE THE PRESSURE ON A FLUID AND TRANSPORT THE FLUID.
- HOWEVER, **GASES ARE COMPRESSIBLE**, THUS COMPRESSORS REDUCE THE VOLUME OF THE GAS



CLASSIFICATIONS OF COMPRESSORS

POSITIVE DISPLACEMENT

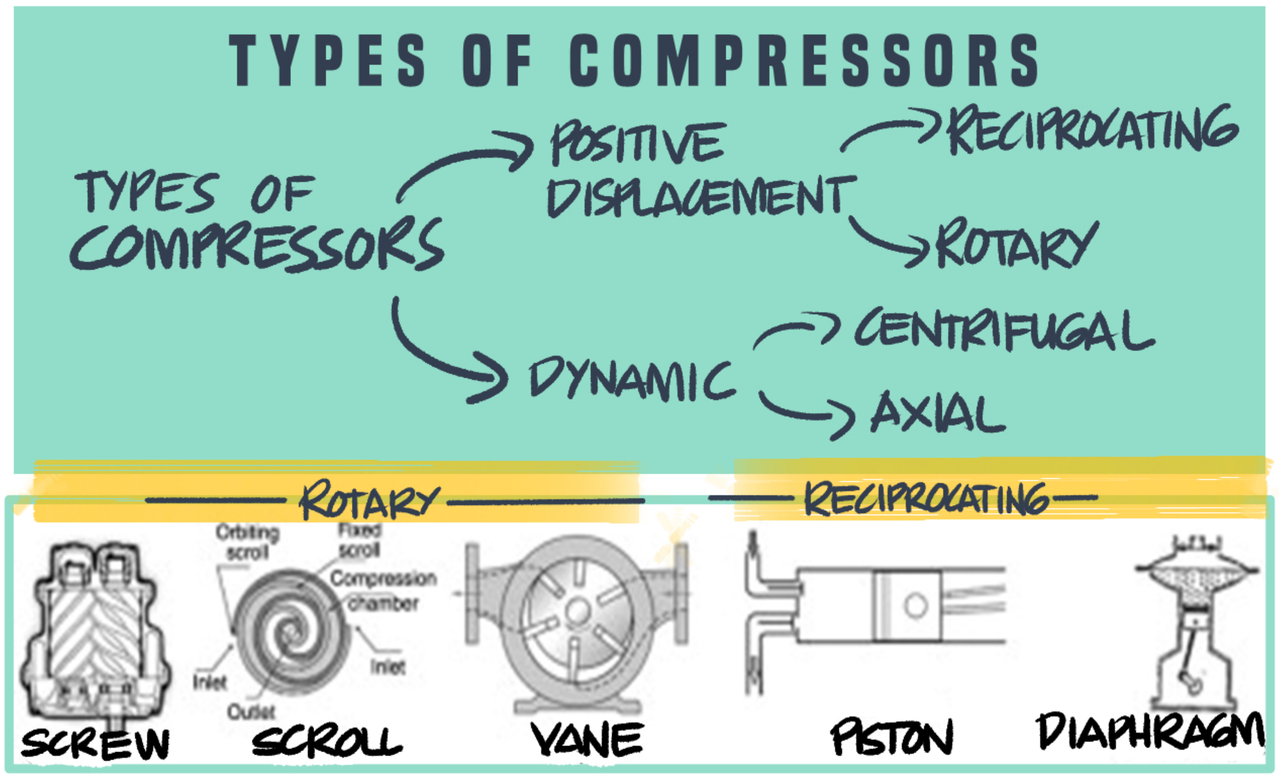
- ARE THOSE IN WHICH **SUCCESSIVE VOLUMES OF AIR ARE CONFINED WITHIN A CLOSED SPACE** AND ELEVATED TO A HIGHER PRESSURE.

- **RECIPROCATING COMPRESSORS**
  - **PISTON OR DIAPHRAGM** HAS A RECIPROCATING MOTION.
- **SCREW (HELICAL OR SPIRAL LOBE) COMPRESSORS**
  - TWO INTERMESHING ROTORS, EACH IN HELICAL CONFIGURATION DISPLACE AND COMPRESS THE AIR.
- **SLIDING-VANE COMPRESSORS**
  - **AXIAL VANES SLIDE RADIALLY** A ROTOR MOTOR MOUNTED **ECCENTRICALLY** WITHIN A CYLINDRICAL CASING.
- **TWO IMPELLER STRAIGHT-LOBE COMPRESSORS**
  - **LOBES IMPELLERS** TRAP THE AIR AND CARRY IT FROM INTAKE TO DISCHARGE.

DYNAMIC COMPRESSORS

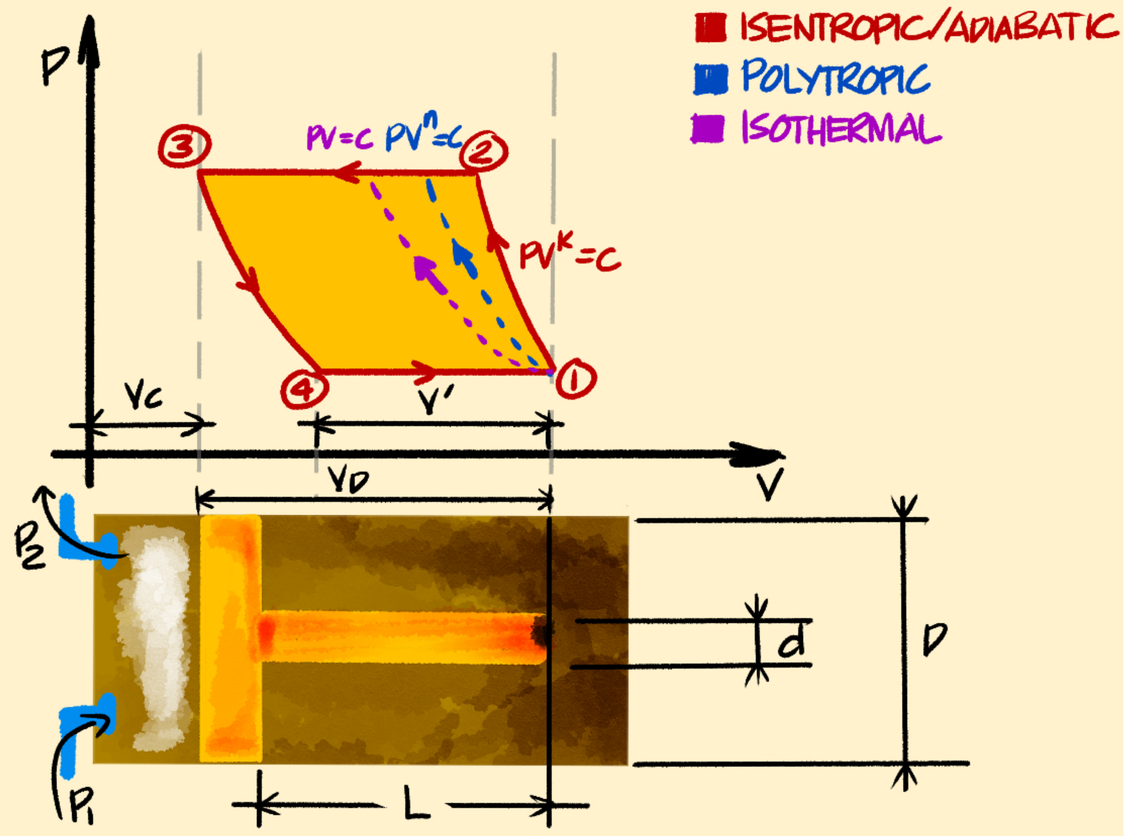
- RAPIDLY ROTATING ELEMENT ACCELERATES THE AIR AS IT PASSES THROUGH THE ELEMENT, CONVERTING THE **VELOCITY HEAD INTO PRESSURE**

- **CENTRIFUGAL COMPRESSORS**
  - ACCELERATION IS OBTAINED THROUGH THE ACTION **OF ONE OR MORE ROTATING IMPELLERS.**
- **AXIAL COMPRESSORS**
  - WHERE ACCELERATION IS OBTAINED THROUGH THE **ACTION OF A BLADED ROTOR,** SHROUDED AT THE BLADE ENDS.



APPLICATIONS OF AIR COMPRESSORS		
COMPRESSORS	**PRESSURE**	**CAPACITY**
RECIPROCATING	HIGH	LOW
ROTARY	MODERATE	LOW
CENTRIFUGAL	LOW	HIGH

SINGLE-STAGE RECIPROCATING COMPRESSOR



P, V, T RELATIONS

n=1.4 ISENTROPIC COMP.
n=1 ISOTHERMAL COMP.

$$P_1V_1^{\,k} = P_2V_2^{\,k} \quad \left| \quad \frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} = \left(\frac{V_1}{V_2}\right)^{K-1} \right.$$

PISTON DISPLACEMENT

$$V_D = \frac{\pi}{4} D^2 L N \times n_c \times n_p$$

n_c = CYLINDERS
n_p = PISTON ACTIONS

PISTON SPEED

$$V = 2LN$$

VOLUMETRIC EFFICIENCY

$$e_V = \frac{V'}{V_D} \quad \left| \quad e_V = 1 + C - C\left(\frac{P_2}{P_1}\right)^{\frac{1}{K}} \right.$$

$$C = \text{CLEARANCE} = \frac{V_c}{V_D}$$

ACTUAL VOLUMETRIC EFFICIENCY

LESS THAN THE CLEARANCE VOL. EFF. BECAUSE OF PRESSURE DROP AT VALVES, HEAT LOSS, AND THE PRESENCE OF RESIDUAL GAS IN THE CYLINDER AT END STROKE

$$e_v = \left[1 + C - C\left(\frac{P_1}{P_2}\right)\right] \times \frac{P_1}{P_{ATM}} \times \frac{T_{ATM}}{T_1}$$

CAPACITY

$$V' = \frac{mRT_1}{P_1}$$

COMPRESSOR WORK

WORK FOR ISENTROPIC COMPRESSION

$$W = \left(\frac{K}{K-1}\right)(P_1V_1')\left[\left(\frac{P_2}{P_1}\right)^{\frac{K-1}{K}} - 1\right]$$

WORK FOR POLYTROPIC COMPRESSION

$$W = \left(\frac{n}{n-1}\right)(P_1V_1')\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

WORK FOR ISOTHERMAL COMPRESSION

$$W = P_1V_1' \ln\left[P_2/P_1\right]$$

COMPRESSOR EFFICIENCY

$$e_c = \frac{\text{COMPRESSOR POWER}}{\text{BRAKE POWER}}$$

IDEAL INDICATED POWER

$$\text{POWER}_i = P_{mi}V_D$$

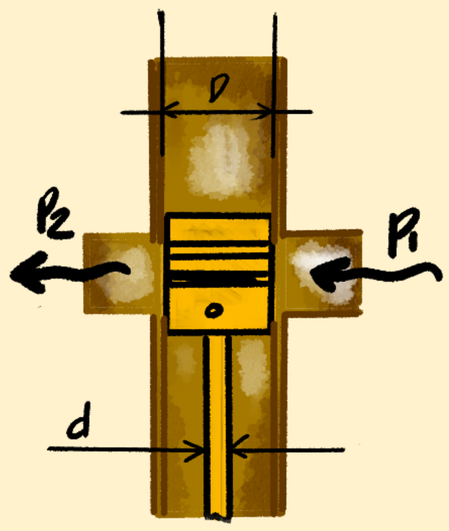
ADIABATIC COMPRESSOR EFFICIENCY

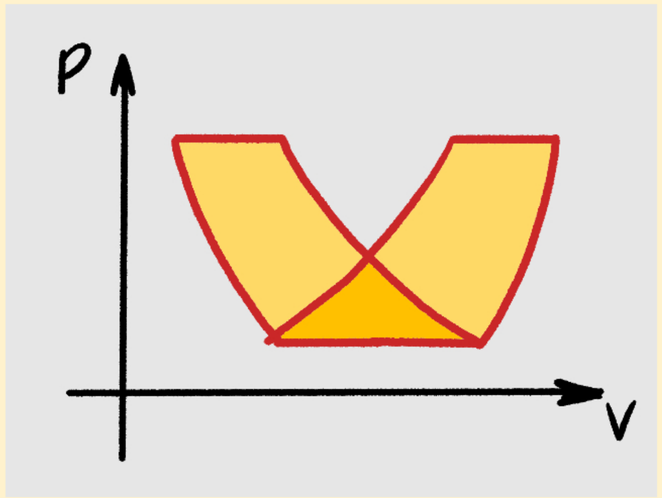
$$e_{c\ ADIABATIC} = \frac{\text{ISENTROPIC WORK}}{\text{ACTUAL FLUID WORK}}$$

ADIABATIC COMPRESSION	MAXIMUM WORK
ISOTHERMAL COMPRESSION	MINIMUM WORK

ISENTROPIC PROCESS	NO COOLING
POLYTROPIC PROCESS	SOME COOLING
ISOTHERMAL PROCESS	MAXIMUM COOLING

DOUBLE ACTING RECIPROCATING COMPRESSOR





PISTON DISPLACEMENT

ROD NEGLECTED

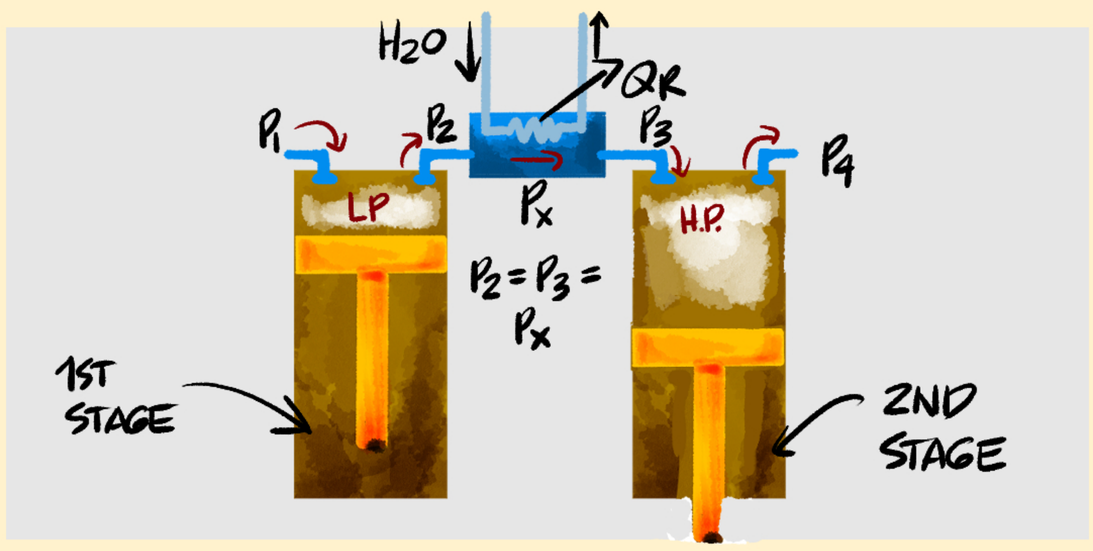
$$V_D = (2)\frac{\pi}{4}D^2LN$$

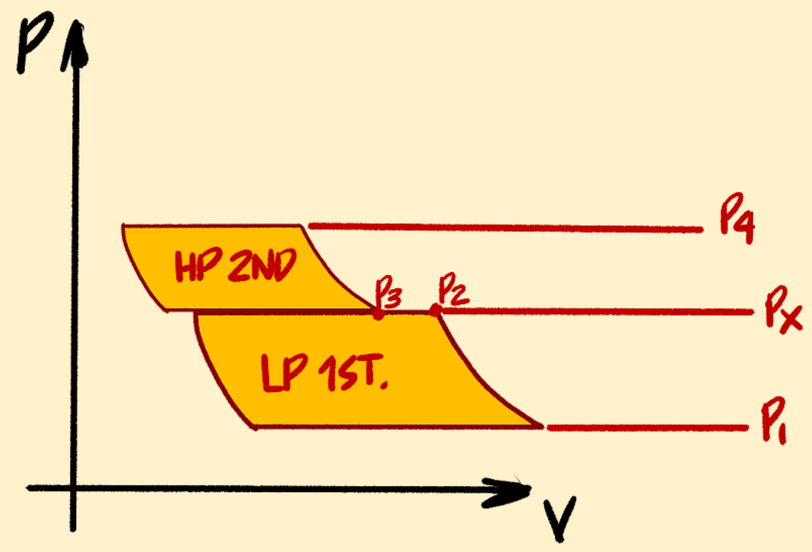
ROD CONSIDERED

$$V_D = \frac{\pi}{4}D^2LN + \frac{\pi}{4}(D^2 - d^2)LN$$

$$V_D = (2)\left(\frac{\pi}{4}D^2LN\right) - \frac{\pi}{4}d^2LN$$

TWO-STAGE RECIPROCATING COMPRESSOR





COMPRESSOR WORK

$$W = (2)\frac{K}{K-1}(P_1V_1')\left[\left(\frac{P_x}{P_1}\right)^{\frac{K-1}{K}} - 1\right]$$

INTERCOOLER PRESSURE

$$P_x = \sqrt{P_1 \times P_4}$$

HEAT ABSORBED BY COOLING WATER

$$Q = mc_{pw}\Delta t_w$$

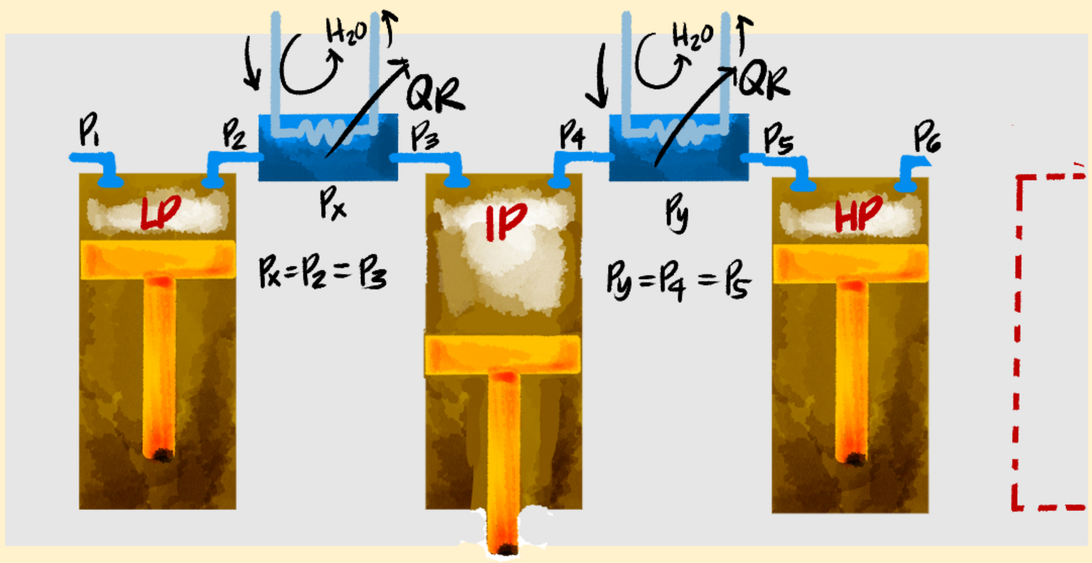
HEAT REJECTED IN THE INTERCOOLER

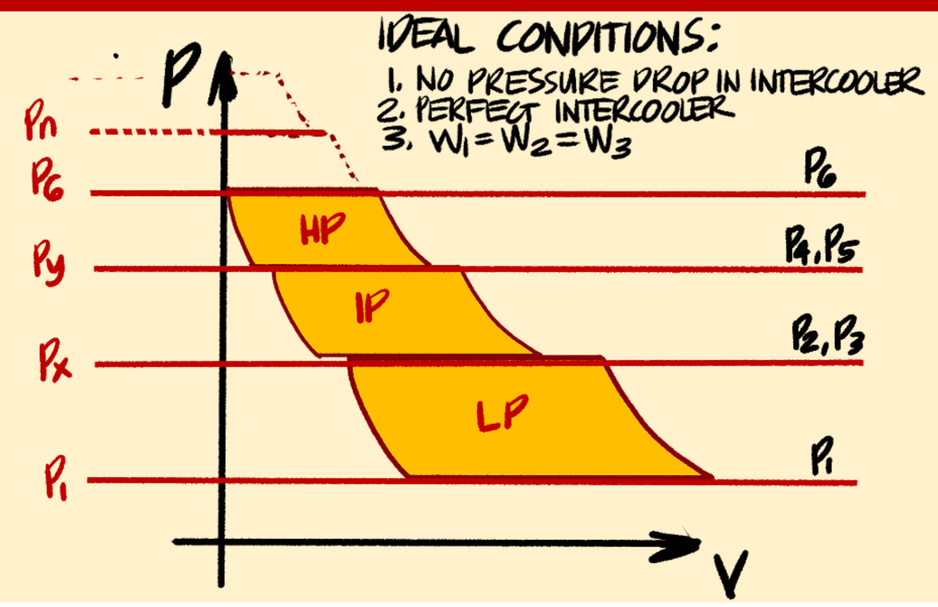
$$Q_R = mc_p(T_x - T_1)$$

WHERE:

$$\frac{T_x}{T_1} = \left(\frac{P_x}{P_1}\right)^{\frac{K-1}{K}} \quad \Big| \quad c_p = 1.0\frac{kJ}{kg\,K}$$

MULTI-STAGE RECIPROCATING COMPRESSOR





COMPRESSOR WORK

GENERAL FORMULA

NOTE: "S" → NO. OF STAGES

$$W=(S)\left(\frac{k}{k-1}\right)(P_1V_1')\left[\left(\frac{P_x}{P_1}\right)^{\frac{k-1}{k}}-1\right]$$

PRESSURE RATIOS (IDEAL CONDITIONS)

$$\frac{P_x}{P_1}=\frac{P_y}{P_x}=\frac{P_6}{P_y}$$

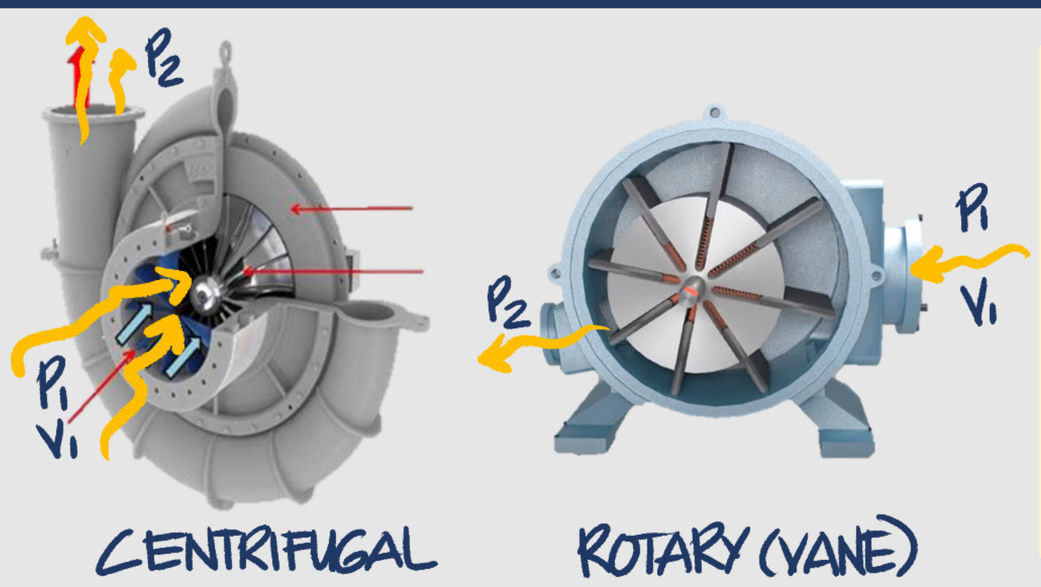
INTERCOOLER PRESSURE

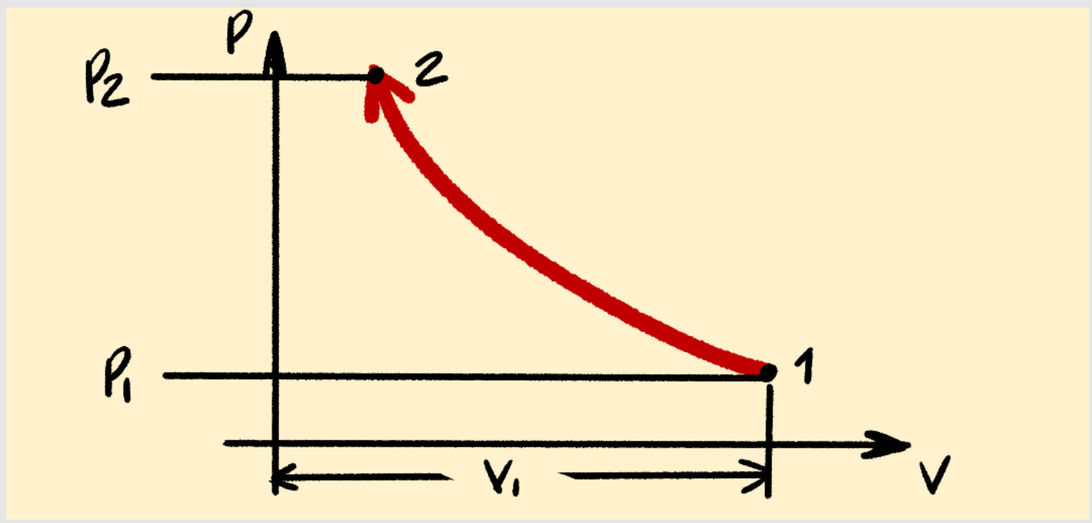
$$P_x=\sqrt[S]{(P_i)^{S-1}(P_f)}$$

HEAT REJECTED IN INTERCOOLER:

$$Q_R=(S-1)[mc_p(T_x-T_i)]$$

CENTRIFUGAL AND ROTARY COMPRESSORS





COMPRESSOR WORK

$$W=\left(\frac{K}{K-1}\right)(P_1V_1)\left[\left(\frac{P_2}{P_1}\right)^{\frac{K-1}{K}}-1\right]$$

BASIC CONVERSION OF COMPRESSION SYS.

● CONVERSION FROM SINGLE-STAGE TO 2-STAGE SYSTEM

$$\text{POWER SAVE} = P_S - P_D$$

$$\%\,\text{POWER SAVE} = \frac{P_S-P_D}{P_S}\times 100\%$$

● CONVERSION FROM 2-STAGE TO SINGLE-STAGE SYSTEM

$$\text{POWER INCREASE} = P_S-P_D$$

$$\%\,\text{POWER INCREASE} = \frac{P_S-P_D}{P_D}\times 100\%$$

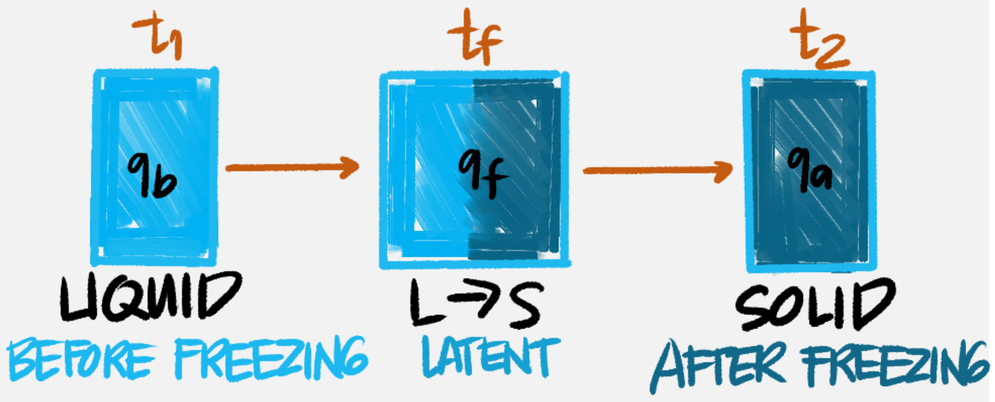
NOTE:
P_S = SINGLE STAGE
P_D = DOUBLE STAGE

REFRIGERATION

- IS DEFINED AS THE **PROCESS OF EXTRACTING HEAT FROM A LOWER-TEMPERATURE HEAT SOURCE**, SUBSTANCE, OR COOLING MEDIUM AND TRANSFERRING IT TO A HIGHER-TEMPERATURE HEAT SINK.

METHODS:
1. MECHANICAL REF.
2. AIR CYCLE REFRIGERATION
3. ABSORPTION REF.
4. ICE REFRIGERATION
5. STEAM JET REFRIGERATION

PRODUCT LOAD



$q_L = q_b + q_f + q_a$

$q_L = m(cp_b(t_1 - t_f)) + (mL_f) + mcp_a(t_f - t_2)$

LATENT HEAT

HEAT BEFORE FREEZING — HEAT AFTER FREEZING

PRODUCT LOAD CONSTANTS

PRODUCT	Cp_b	Cp_a	LATENT HEAT
WATER	4.187 kJ/kgK	2.093 kJ/kgK	335 kJ/kg = 144 BTU/lb
BRINE	Cp = 3.76 kJ/kgK		
VEGETABLES	Cp = 3.35 kJ/kgK		
POULTRY	3.18 kJ/kgK	1.55 kJ/kgK	246 kJ/kg
LEAN BEEF	3.23 kJ/kgK	1.68 kJ/kgK	233 kJ/kg
FISH (TUNA)	0.7 kcal/kgK	0.3 kcal/kgK	55.5 kcal/kg
MILK	Cp = 3.9 kJ/kgK		Sg = 1.05
MAGNOLIA	Cp = 0.935 BTU/lbm°R		sg = 1.03

BASIC COMPONENTS OF A REF SYSTEM

COMPRESSOR

- COMPRESSES THE **LOW-PRESSURE REFRIGERANT GAS TO A HIGH-PRESSURE REFRIGERANT GAS** AND CAUSE TO TO FLOW IN THE SYSTEM.
- **HEART** OF THE VAPOR COMPRESSION SYSTEM

TYPES OF COMPRESSORS

RECIPROCATING | ROTARY | CENTRIFUGAL

CLASSIFICATION OF COMPRESSOR BASED ON ENCLOSURE

OPEN-TYPE	CRANKSHAFT EXTENDS THROUGH THE COMPRESSOR HOUSING SO THAT THE MOTOR CAN BE **EXTERNALLY COUPLED** TO SHAFT
HERMETICALLY SEALED	**COMPRESSOR AND THE MOTOR** ARE ENCLOSED IN THE SAME HOUSING
SEMI-HERMETIC	THE **CYLINDER HEAD CAN BE REMOVED** FOR SERVICING OF THE VALVE AND PISTONS

EVAPORATOR

- LIQUID PORTION EVAPORATES WHILE ABSORBING HEAT FROM THE SURROUNDINGS

TYPES OF EVAPORATORS

DIRECT EXPANSION (DRY TYPE)	COIL TUBING BETWEEN METERING DEVICE AND COMPRESSOR **TYPES OF DRY EVAPORATORS:** A. **BEAR TYPE** – PRIME SURFACE, SIMPLEST B. **PLATE TYPE** – SHEETS WELDED TO TUBINGS C. **FIN-TUBE** D. **SHELL AND COIL** – ALSO CALLED CHILLER
FLOODED EVAP.	ONLY FOR WATER-COOLED CONDENSERS. HIGH CAPACITY SYSTEMS.

CONDENSER

- RECEIVES THE HIGH-PRESSURE REFRIGERANT GAS AND THEN CONDENSES WHILE **REJECTING HEAT** TO THE COOLING MEDIUM (AIR OR WATER).
- LIQUEFY THE REFRIGERANT

TYPES OF CONDENSERS

AIR-COOLED	COMMON IN SMALL COMMERCIAL SYSTEMS. **TYPES OF AIR-COOLED CONDENSERS:** A. **NATURAL DRAFT** – AMBIENT AIR B. **FORCED DRAFT** – PUSHED THROUGH COILS C. **INDUCED AIR DRAFT** – PUSHED OVER OILS
WATER-COOLED	EXPENSIVE AND CORROSIVE **TYPES OF WATER-COOLED CONDENSERS:** A. **DOUBLE PIPE**– (TUBE-IN-TUBE) REFRIGERANT THROUGH INNER TUBE AND WATER THROUGH OUTER TUBE B. **SHELL AND COIL** – MADE OF STEEL WITH COPPER TUBES INSIDE C. **VERTICAL SHELL AND TUBE** D. **HORIZONTAL SHELL AND TUBE**
EVAPORATIVE	MUCH LIKE A **COOLING TOWER**. WATER IS SPRAYED OVER THE CONDENSER AND COOLS IT.

ACCESORIES

1. **SPRAY POND** – WATER RECIRCULATING DEVICE. WARM WATER IS SPRAYED THROUGH NOZZLE.
2. **COOLING TOWERS**

TUBINGS

COPPER/BRASS	MOST REF. APPLICATIONS
STEEL	AMMONIA (R717)
STAINLESS STEEL	FOOD PROCESSING, MILK ICE CREAM
PLASTIC TUBING	COLD WATER LINES, WATER COOLED CONDENSERS.

THROTTLING | EXPANSION DEVICE

- REDUCES THE PRESSURE FROM CONDENSER PRESSURE TO EVAPORATOR PRESSURE
- REGULATE FLOW RATE OF REFRIGERANT

TYPES OF EXPANSION DEVICES

CAPILLARY TUBE (SMALL REF. SYSTEMS)

INSIDE DIAMETER	0.50 mm – 2 mm
LENGTH	1m – 6 m
CAPACITY	up to 10 kW

EXPANSION VALVES

TYPES:

A. GATE VALVE
B. CONSTANT PRESSURE EXPANSION VALVE
C. THERMOSTATIC EXPANSION VALVE
D. THERMOSTATIC EXPANSION VALVE W/ EXTERNAL EQUALIZER
E. FLOAT VALVE (FOR FLOODED EVAPS.)

FLOAT VALVE

- MAINTAINS LIQUID AT CONSTANT LEVEL
- A "**FLOAT SWITCH**" CLOSES AT MAX. LEVEL

CONSTANT PRESSURE E.V.

- MAINTAINS CONSTANT PRESSURE AT ITS OUTLET (ENTRANCE TO EVAPORATOR)

SUPERHEAT CONTROLLED E.V.

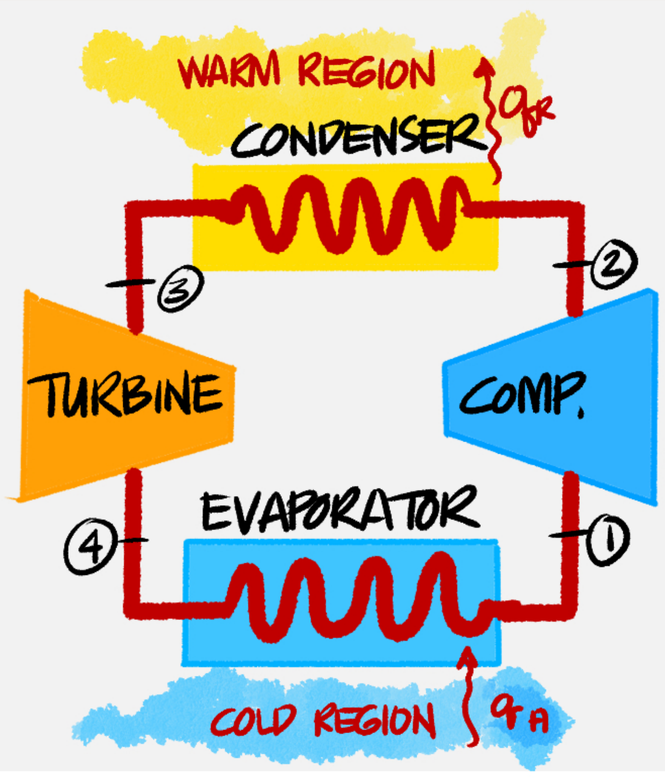
- MOST POPULAR FOR MODERATE-SIZE REF. SYSTEMS
- "**THERMOSTATIC E.V**"
- **REGULATES THE FLOW RATE** OF LIQUID REFRIGERANT IN **PROPORTION TO THE RATE OF EVAPORATION** IN THE EVAPORATOR

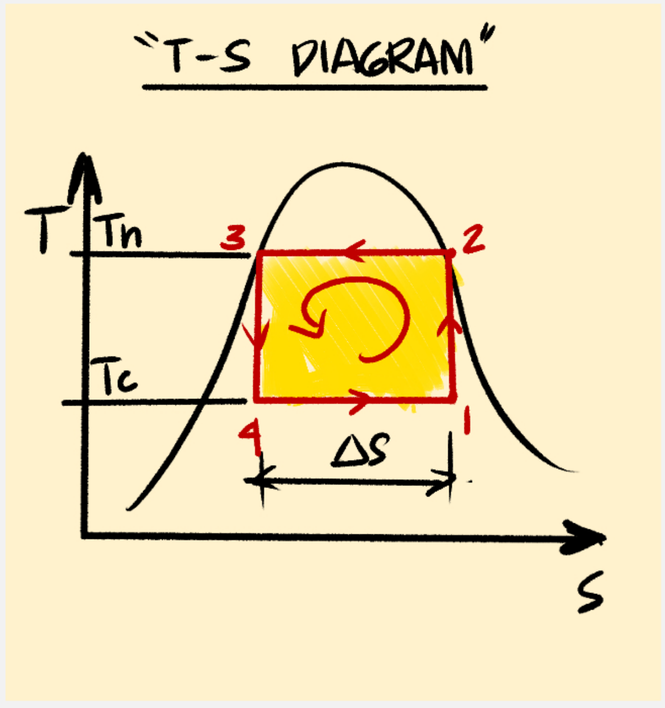
TONS OF REFRIGERATION

- IS THE AMOUNT OF HEAT THAT MUST BE EXTRACTED TO FREEZE **1** TON (SHORT) OF WATER AT **32** F INTO ICE AT **32** F (AT **1** ATM) IN **1** DAY.
- ALSO CALLED **REFRIGERATION TON**

$$1\ TOR = 3.516\ kW = 211\ \frac{kJ}{min} = 50.4\ \frac{kJ}{min} = 200\ \frac{BTU}{min}$$

REVERSED CARNOT CYCLE





HEAT ADDED

$$Q_A = Q_{in} = T_c \Delta S$$

HEAT REJECTED

$$Q_R = Q_{out} = T_h \Delta S$$

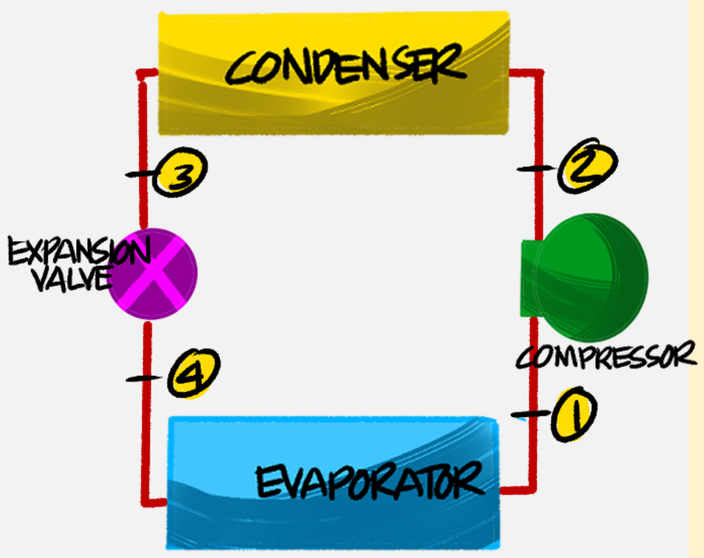
COP (HEAT PUMP)

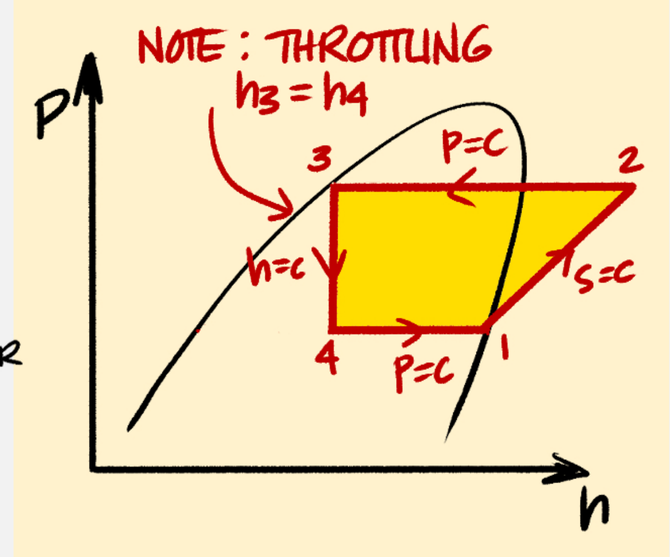
$$COP_{HP} = \frac{T_H}{T_H - T_C}$$

COP (REFRIGERATION)

$$COP_{REF} = \frac{T_C}{T_H - T_C}$$

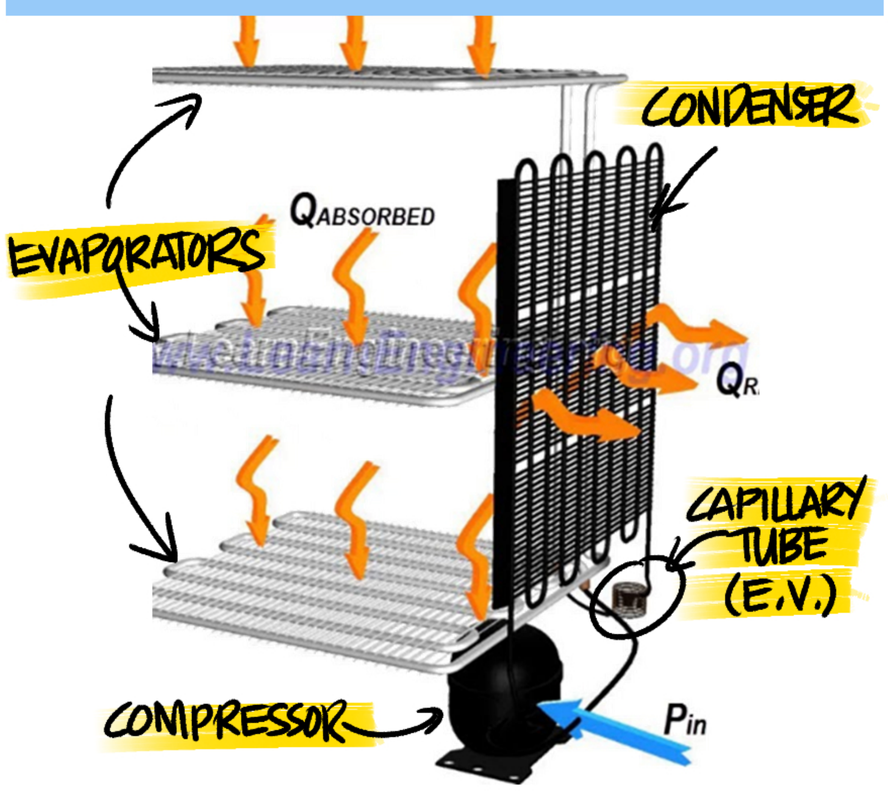
VAPOR COMPRESSION SYSTEM





1 - 2	ISENTROPIC COMPRESSION
2 - 3	CONSTANT PRESSURE CONDENSATION
3 - 4	ISENTHALPIC EXPANSION IN E.V. (IRREV.)
4 - 1	CONSTANT PRESSURE VAPORIZATION

- VAPOR COMPRESSION SYSTEMS ARE THE MOST **WIDELY ADOPTED** REFRIGERATION SYSTEMS IN BOTH COMFORT AND PROCESS AIR CONDITIONING.
- ALSO CALLED **REVERSED RANKINE CYCLE.**



COMPRESSOR WORK

$$W_c = m(h_2 - h_1)$$

ENTHALPY AT EVAP. ENTRANCE (4)

$$h_4 = h_{f4} + \underline{\underline{x}} h_{fg4} \quad | \quad x = \text{QUALITY \%}$$

REFRIGERATING CAPACITY

$$q_{fL} = m(h_1 - h_4)$$

POWER PER TON

$$\text{POWER PER TON} = \frac{W_c}{\text{TON OF REF.}}$$

$$\frac{kW}{kW} = \frac{1}{TOR} \quad | \quad \frac{HP}{TON} = \frac{4.71}{COP} \quad | \quad \frac{kW}{TON} = \frac{3.516}{COP}$$

COP (COEFFICIENT OF PERF.)

$$COP = \frac{\text{REF. CAPACITY}}{\text{COMPRESSOR WORK}} = \frac{q_{fL}}{W_c}$$

EER (ENERGY EFF. RATIO)

RATIO OF ENERGY REMOVED AT THE EVAP. TO THE ELECTRICAL ENERGY CONSUMED. SHALL CONFORM TO THE DEPARTMENT OF ENERGY

$$EER = \frac{\text{REF. EFFECT}}{\text{POWER INPUT}} = 3.412\,COP$$

REFRIGERATION EFFICIENCY

$$e_R = \frac{COP_{SYSTEM}}{COP_{CARNOT}} \times 100\%$$

STANDARD REFRIGERATION CYCLE

EVAPORATION TEMP.

CONDENSING TEMP.

VOLUMETRIC EFFICIENCY

$$\eta_v = \frac{V_1'}{V_D}$$

MECH'L EFFICIENCY

$$e_m = \frac{P_i}{P_b}$$

COMPRESSORS

DISPLACEMENT RATE OF COMPRESSOR

$$V_D = \frac{\pi}{4} D^2 L N \times n_c \quad | \quad \text{NOTE} = \times 2 \text{ IF DOUBLE ACTING}; \; n_c = \text{NO. OF CYLINDERS}$$

VOLUME FLOW RATE AT SUCTION

$$V_1' = mv_1 \quad | \quad v_1 = \text{SPECIFIC VOLUME } \frac{m^3}{kg}$$

CLEARANCE VOLUMETRIC EFFICIENCY

$$e_{Vc} = 1 + C - C(r_p)$$

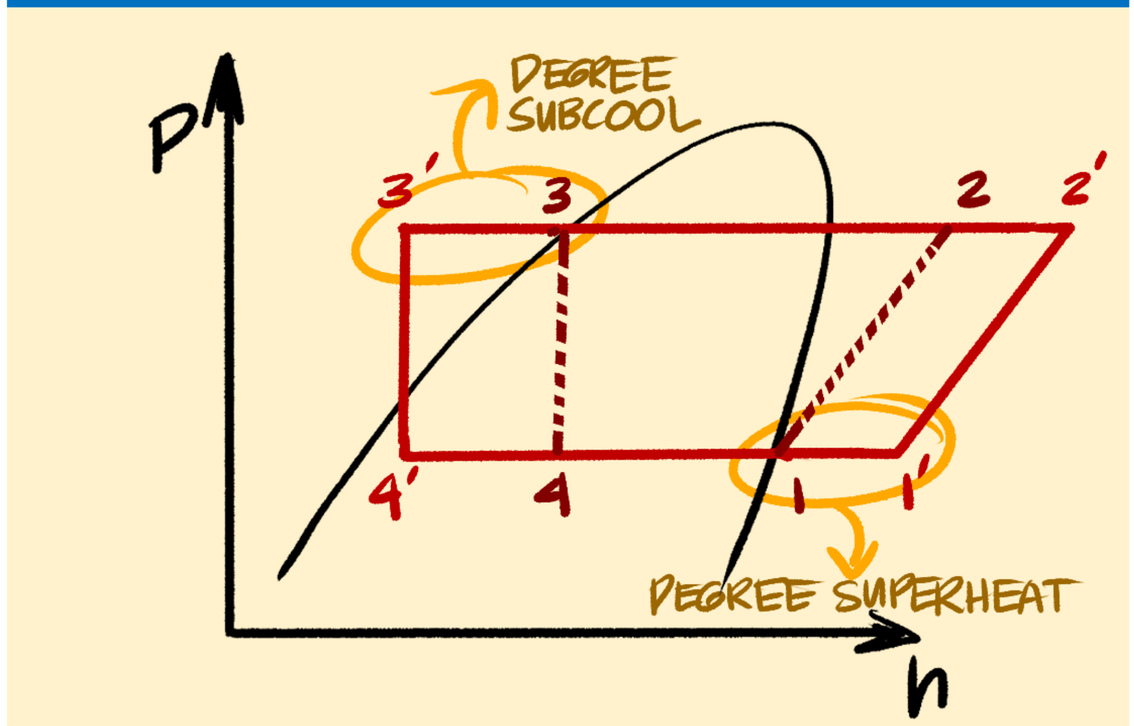
$$r_p = \frac{V_1}{V_2} = \left(\frac{P_2}{P_1}\right)^{\frac{1}{k}}$$

C = PERCENT CLEARANCE

r_p = COMPRESSION RATIO

FOR AMMONIA, USE $k = 1.4$

DEGREE SUPERHEATING AND DEGREE SUBCOOLING



DEGREE SUPERHEATING

DIFFERENCE BETWEEN ACTUAL TEMPERATURE ENTERING THE COMPRESSOR AND THE EVAPORATOR TEMPERATURE

$$^{o}SH = t_1' - t_{EVAP}$$

DEGREE SUBCOOLING

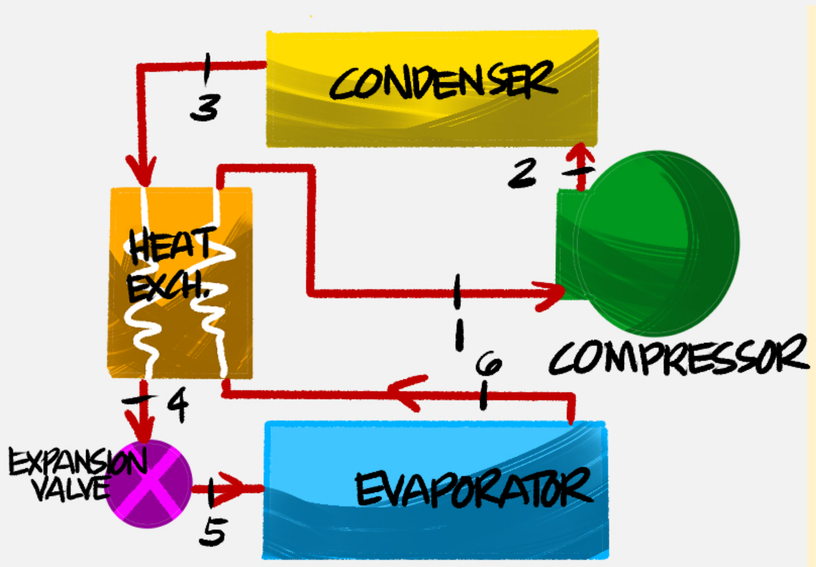
DIFFERENCE BETWEEN CONDENSER TEMPERATURE AND THE ACTUAL TEMPERATURE ENTERING THE EXPANSION VALVE.

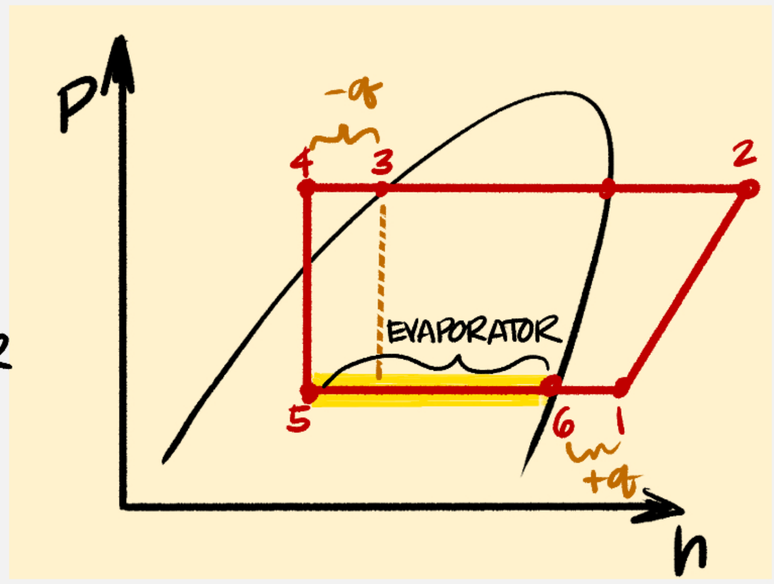
ADVANTAGES:

- REDUCES QUALITY OF GAS VAPOR
- INCREASES REFRIGERATING EFFECT OF SYSTEM

$$^{o}SC = t_{COND} - t_3'$$

W/ HEAT EXCHANGER





HEAT EXCHANGERS

- PREVENT NO LIQUID ENTERS COMPRESSOR
- PREVENT BUBBLES OF VAPOR THROUGH E.V.

ENERGY BALANCE

$$h_3 + h_6 = h_1 + h_4$$

COP

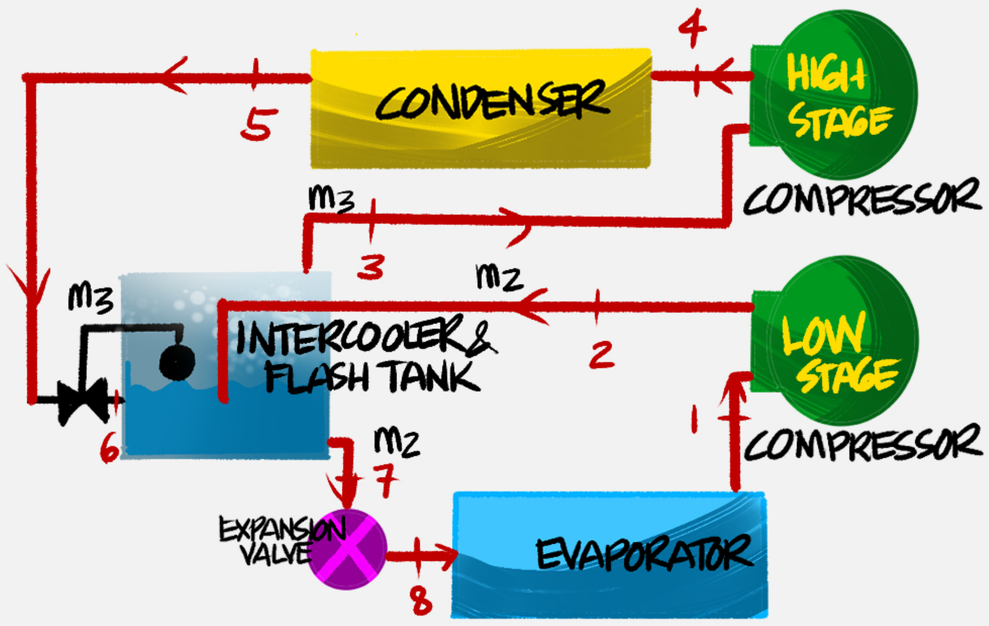
REF. EFFECT

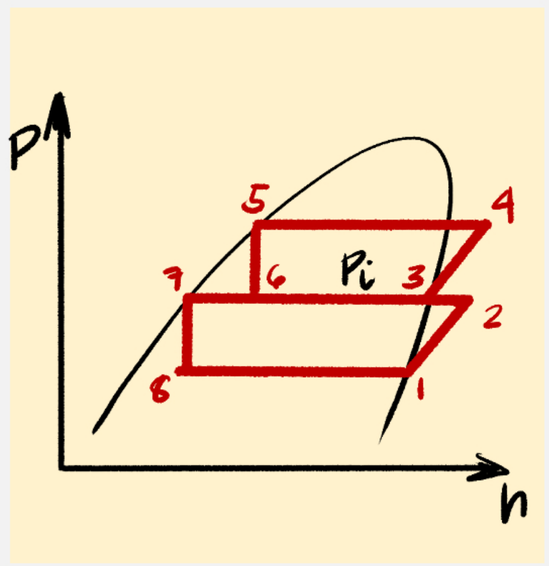
$$P = \frac{h_6 - h_5}{h_2 - h_1} \quad | \quad q_{fL} = \text{CONSIDER THE "q" ONCE ONLY}$$

MULTI PRESSURE SYSTEMS

- THESE ARE REFRIGERATION SYSTEMS WITH TWO OR MORE LOW-SIDE PRESSURES.
- LOW-SIDE PRESSURE IS DEFINED AS THE REFRIGERANT PRESSURE BETWEEN EXPANSION VALVE AND COMPRESSOR INTAKE.
- **INTERCOOLER** – REDUCES THE WORK PER KILOGRAM OF VAPOR BETWEEN TWO STAGES OF COMPRESSION; MAY BE ACCOMPLISHED BY A WATER-COOLED HEAT EXCHANGER OR BY USING A REFRIGERANT.
- **FLASH TANK** – EQUIPMENT IN WHICH VAPOR IS SEPARATED FROM THE LIQUID.

I. TWO STAGE COMPRESSOR, ONE EVAPORATOR





$$P_i = \sqrt{P_1 \times P_4}$$

$$q_{f_L} = m_1 (h_1 - h_8)$$

ENERGY BALANCE:

$$m_2 h_2 + m_6 h_6 = m_7 h_7 + m_3 h_3$$

$$m_2 = m_7$$

$$m_3 = m_6$$

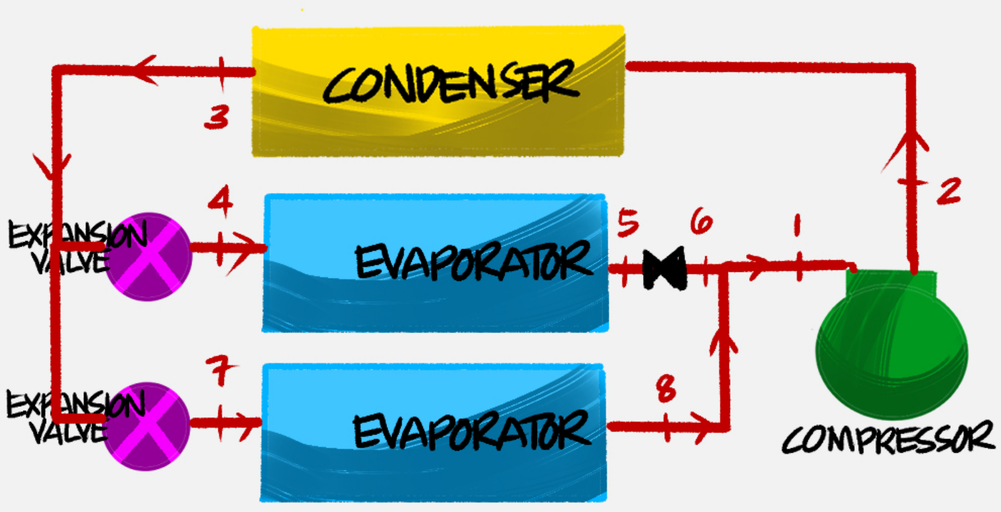
COMPRESSOR WORK

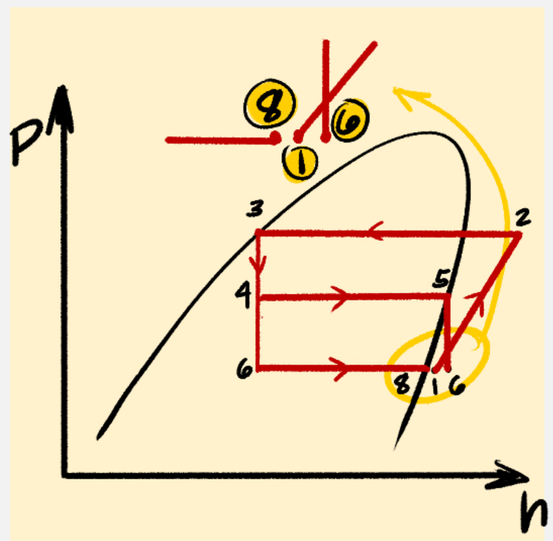
$$W_{CL} = m_1 (h_2 - h_1)$$

$$W_{CH} = m_3 (h_4 - h_3)$$

$$W_{C\,TOTAL} = W_{CL} + W_{CH}$$

II. TWO EVAPORATORS, ONE COMPRESSOR





$$m_1 = m_6 + m_8 = m_4 + m_7$$

$$m_1 h_1 = m_6 h_6 + m_8 h_8$$

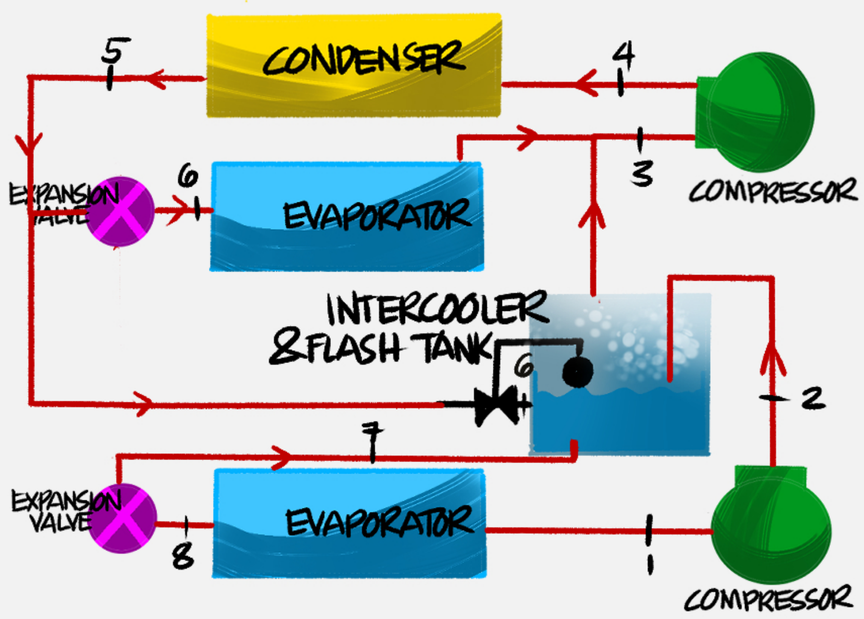
$$W_C = m_1 (h_2 - h_1)$$

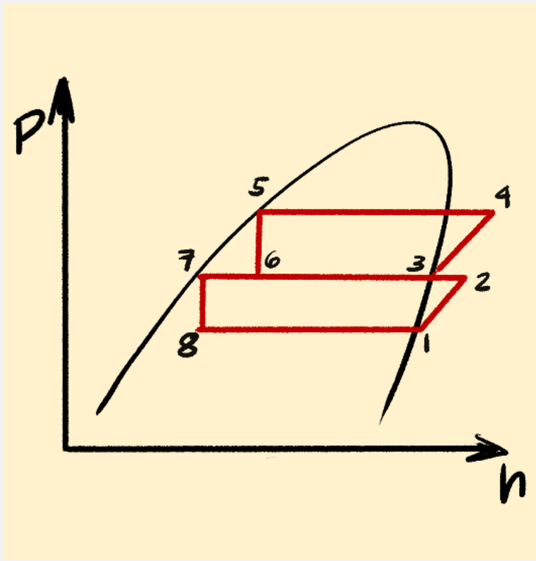
$$q_{f_H} = m (h_8 - h_7$$

$$q_{f_{L2}} = m (h_5 - h_4)$$

$$COP = \frac{q_{L1} + q_{L2}}{W_C}$$

II. TWO EVAPORATORS, TWO COMPRESSOR





$$m_3 = m + m_6$$

$$m h_6 + m_2 h_2 = m_3 h_3 + m_7 h_7$$

$$q_{f_{LH}} = m_6 (h_3 - h_6)$$

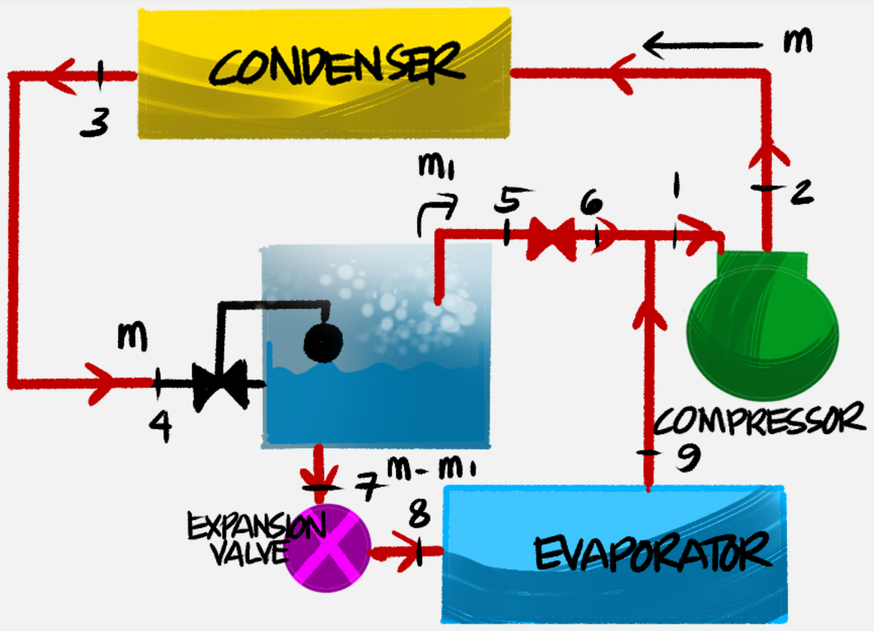
$$q_{f_{LL}} = m_7 (h_1 - h_8)$$

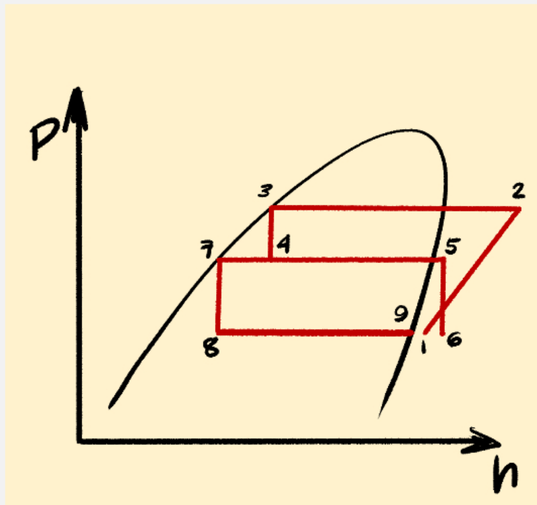
$$W_{CH} = m_3 (h_4 - h_3)$$

$$W_{CL} = m_1 (h_2 - h_1)$$

$$COP = \frac{q_{LH} + q_{LL}}{W_{CH} + W_{CL}}$$

IV. REF. SYSTEM WITH FLASH TANK





FLASH TANK

HEAT BALANCE:

$$mh_4 = m_1h_5 + (m-m_1)h_7$$

JUNCTION

HEAT BALANCE:

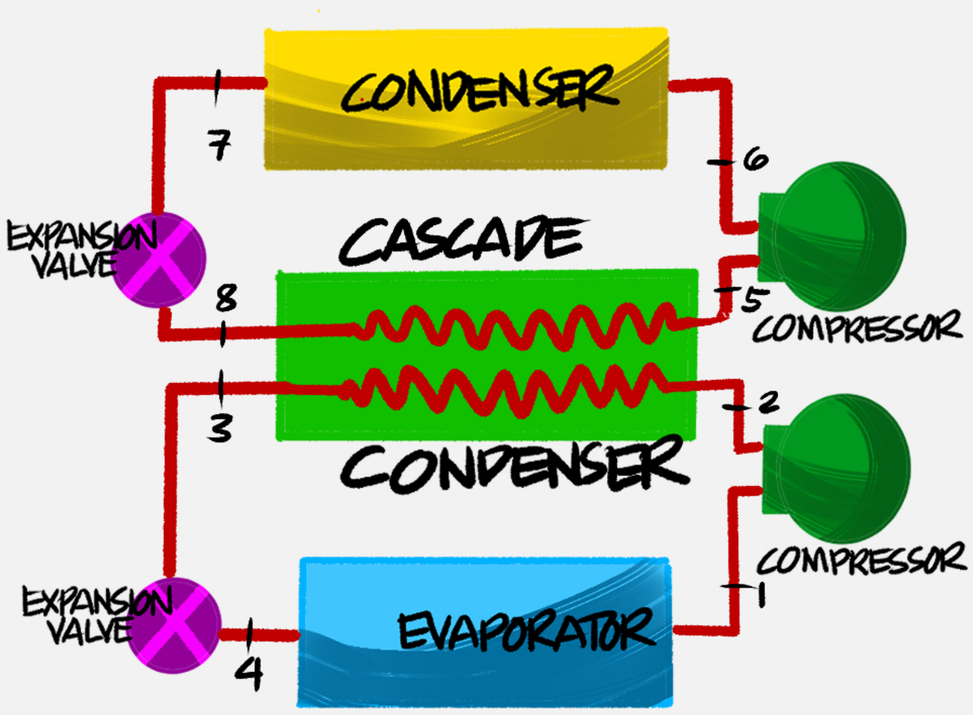
$$mh_1 = (m-m_1)h_9 + m_1h_6$$

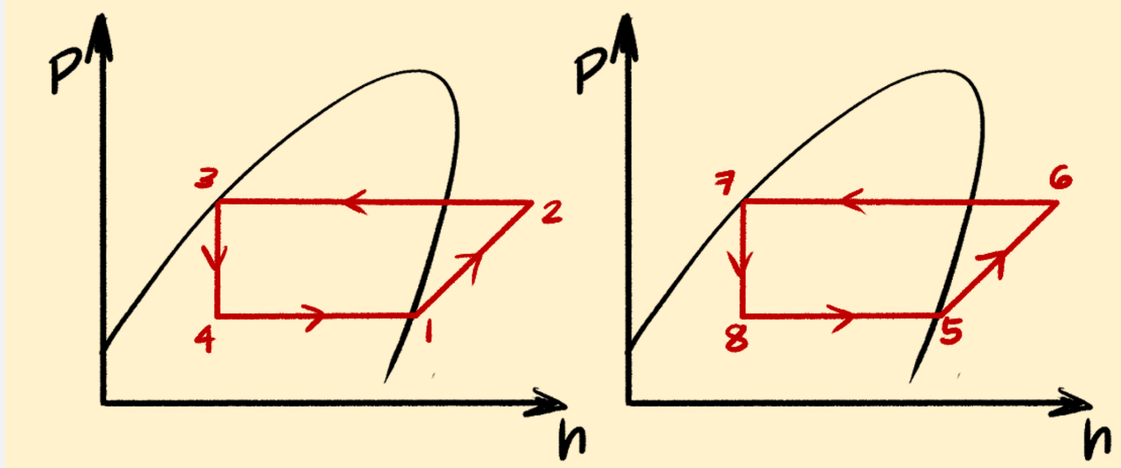
LOW TEMPERATURE REFRIGERATION

- **COMBINE TWO-VAPOR COMPRESSION UNITS**, WITH THE CONDENSER OF THE LOW-TEMPERATURE SYSTEM DISCHARGING ITS HEAT TO THE EVAPORATOR OF THE HIGH-TEMPERATURE SYSTEM.

CRYOGENICS — THE SCIENCE OF **LOW TEMPERATURE**

CLOSED-CASCADE SYSTEM





$$m_5h_5 + m_1h_3 = m_5h_8 + m_1h_2$$

$$m_1(h_2 - h_3) = m_5(h_5 - h_8)$$

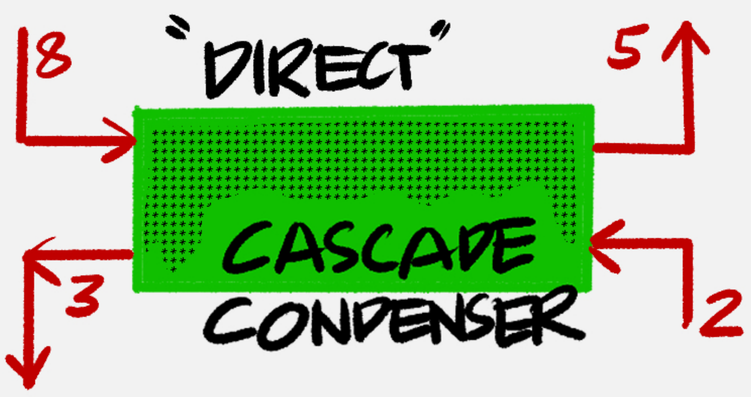
$$Q_L = m_1(h_1 - h_4)$$

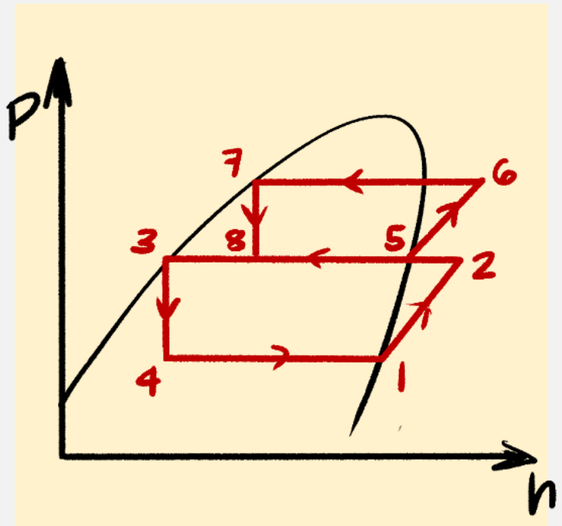
$$W_{CH} = m_5(h_6 - h_5)$$

$$W_{CL} = m_1(h_2 - h_1)$$

$$W_{TOT} = W_{CL} + W_{CH}$$

DIRECT CONTACT CASCADE





$$P_2 = \sqrt{P_1 \times P_6}$$

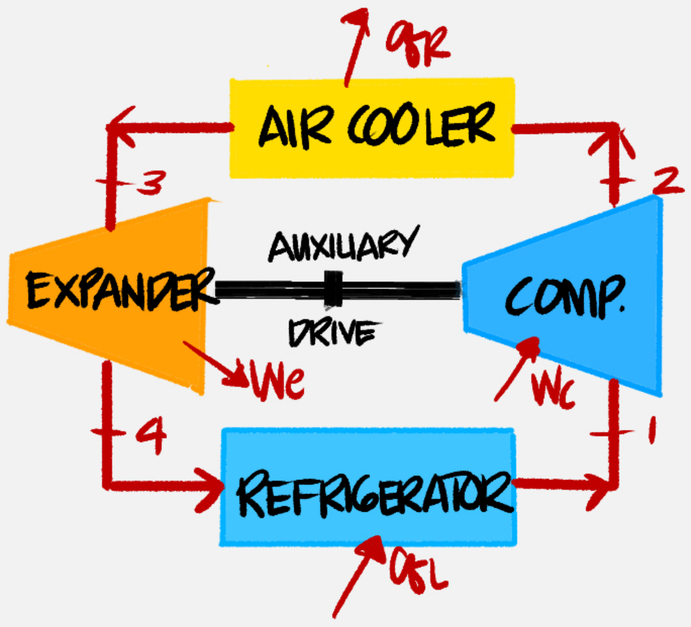
HEAT BALANCE:

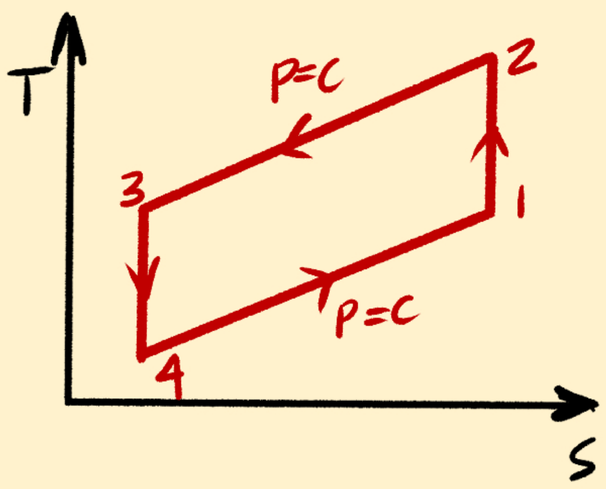
$$m_5(h_5 - h_8) = m_1(h_2 - h_3)$$

TOTAL COMPRESSOR WORK:

$$W_G = m_1(h_2 - h_1) + m_5(h_6 - h_5)$$

AIR-CYCLE REFRIGERATION





- IS OPERATING ON **THE REVERSE BRAYTON CYCLE**
- IT IS THE ONLY AIR-COOLING PROCESS DEVELOPED COMMERCIALLY WHEREIN A **GASEOUS REFRIGERANT IS USED** THROUGHOUT THE CYCLE
- IDEALLY SUITED FOR USE IN AIRCRAFT

1 - 2	ISENTROPIC COMPRESSION
2 - 3	CONSTANT PRESSURE CONDENSATION
3 - 4	ISENTHALPIC EXPANSION IN E.V. (IRREV.)
4 - 1	CONSTANT PRESSURE VAPORIZATION

REFRIGERATION EFFECT

$$q_{\mathfrak{L}} = mC_{pa}(T_1 - T_4)$$

HEAT REJECTED

$$q_R = mC_{pa}(T_2 - T_3)$$

COMPRESSOR WORK

$$W_C = \frac{K}{K-1}(P_1V_1)\left[\left(\frac{P_2}{P_1}\right)^{\frac{K-1}{K}} - 1\right] = \frac{n}{n-1}(P_1V_1)\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right]$$

EXPANSION WORK

$$W_C = \frac{K}{K-1}(P_3V_3)\left[\left(\frac{P_4}{P_3}\right)^{\frac{K-1}{K}} - 1\right] = \frac{n}{n-1}(P_3V_3)\left[\left(\frac{P_4}{P_3}\right)^{\frac{n-1}{n}} - 1\right]$$

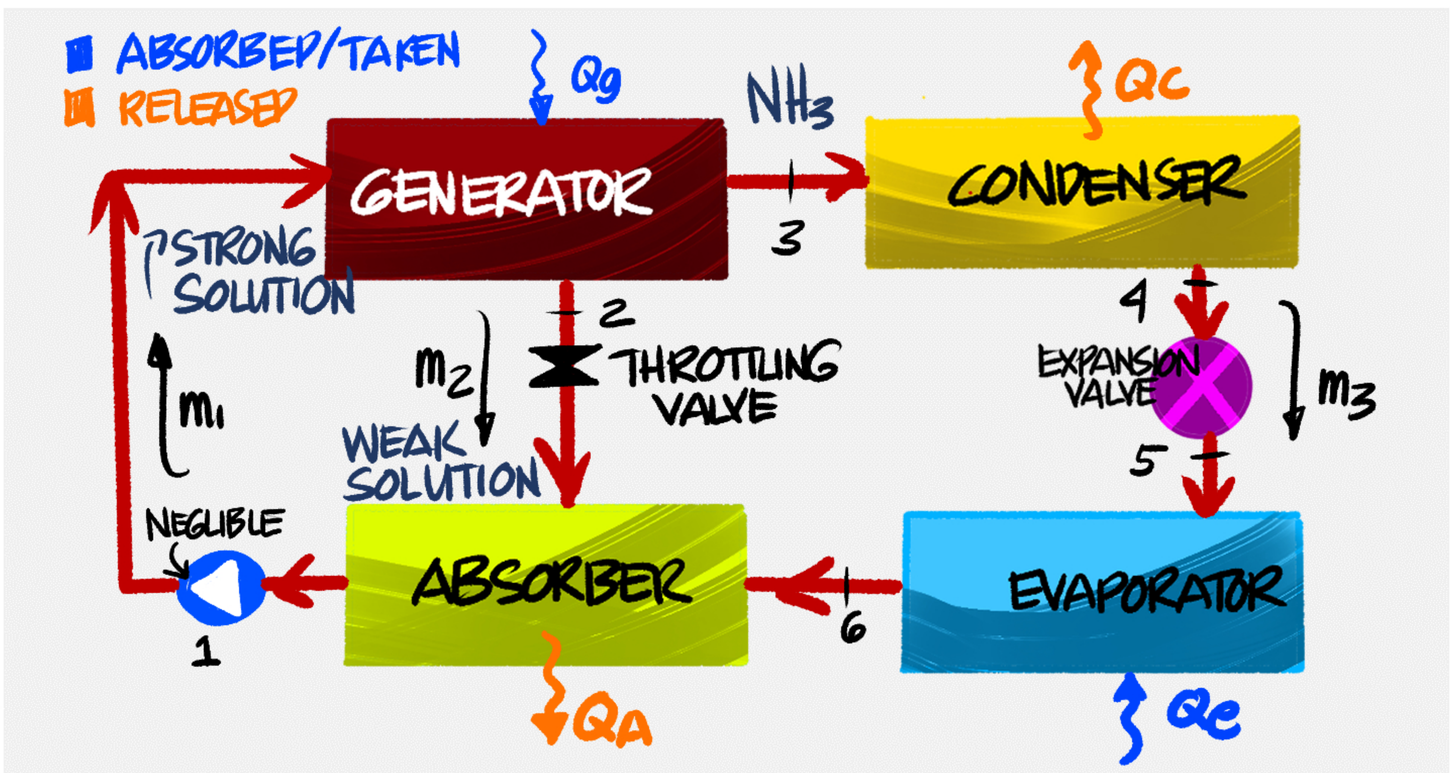
NET WORK

$$W_{NET} = W_C - W_e$$

COEFFICIENT OF PERFORMANCE

$$COP = \frac{q_{\mathfrak{L}}}{W_{NET}}$$

ABSORPTION REFRIGERATION SYSTEM



EXAMPLE: "$NH_3 - H_2O$" SYSTEM

- A REFRIGERATION **WITHOUT COMPRESSOR** AND RATHER NO EXTERNAL WORK TO COMPRESS THE REFRIGERANT.
- A SUBSTITUTE TO THE COMPRESSOR IS THE ABSORBER-GENERATOR SET-UP THAT PRODUCES A SOLUTION OF REFRIGERANT AND THE REFRIGERANT IS SUPERHEATED BY AN EXTERNAL HEAT.

COEFFICIENT OF PERF.

$$COP = \frac{Qe \text{ (USEFUL OUTPUT)}}{Qg \text{ (INPUT NEEDED)}}$$

GENERATOR HEAT

$$Q_g + m_1h_1 = m_3h_3 + m_2h_2$$

CONDENSER HEAT

$$Q_c = m_3(h_3 - h_4)$$

EVAPORATOR HEAT

$$Qe = m_3(h_5 - h_4)$$

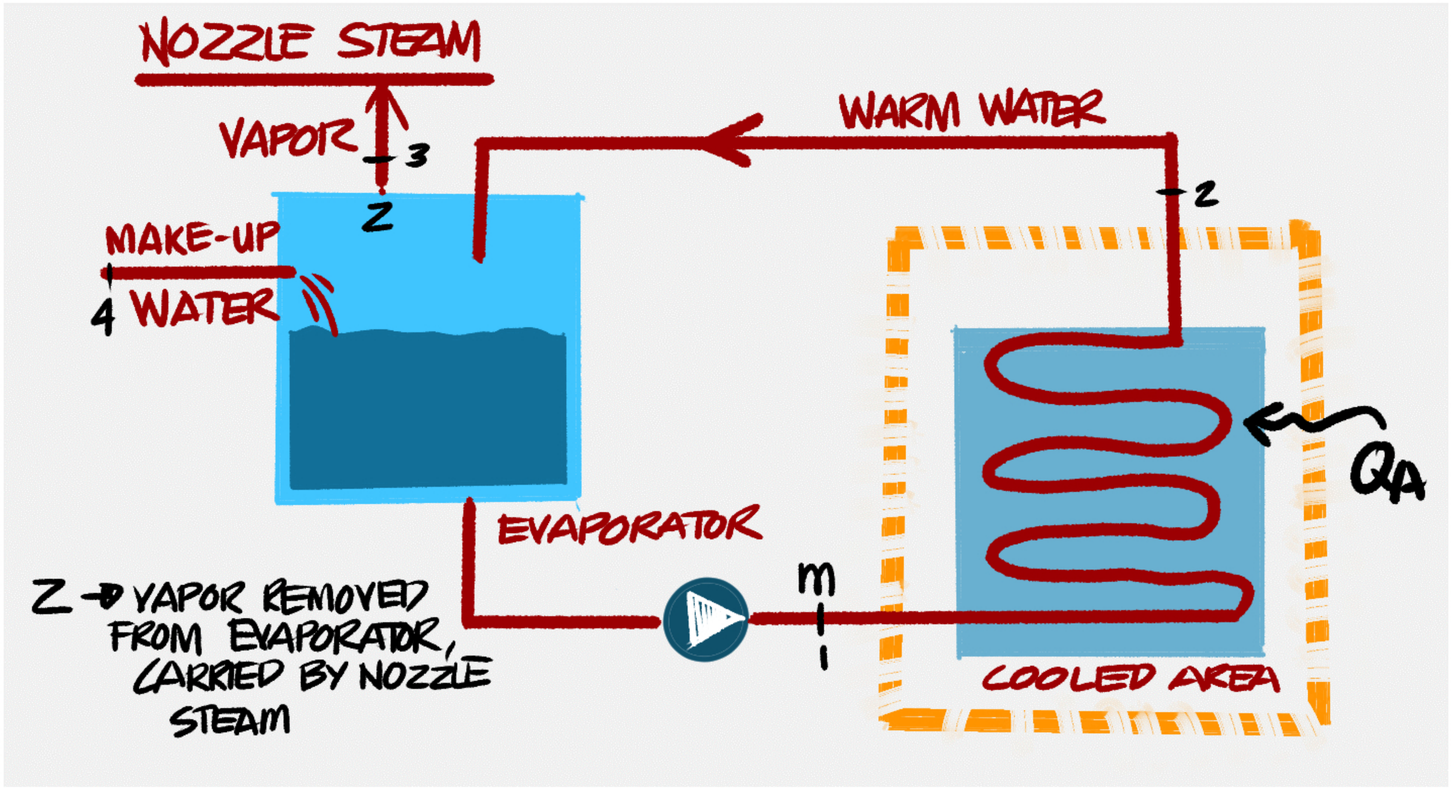
ABSORBER HEAT

$$m_2h_2 + m_3h_6 = Q_A + m_1h_1$$

MASS AND ENERGY BALANCE

- MASS BALANCE: $m_1 = m_2 + m_3$
- ENERGY BALANCE: $Q_g + Qe = Q_A + Q_c$

STEAM JET REFRIGERATION SYSTEM



- WATER IS USED AS REFRIGERANT
- PRINCIPLE OF OPERATION BASED ON THE FACT THAT WATER WILL BOIL OR VAPORIZE RAPIDLY, AT A RELATIVELY LOW TEMPERATURE, IF THE PRESSURE ON THE SURFACE IS REDUCED.

MASS AND ENERGY BALANCE

HEAT BALANCE:

$$Q_A = z(h_3 - h_4)$$

h_4 → h_f @ TEMP. MAKE-UP H_2O

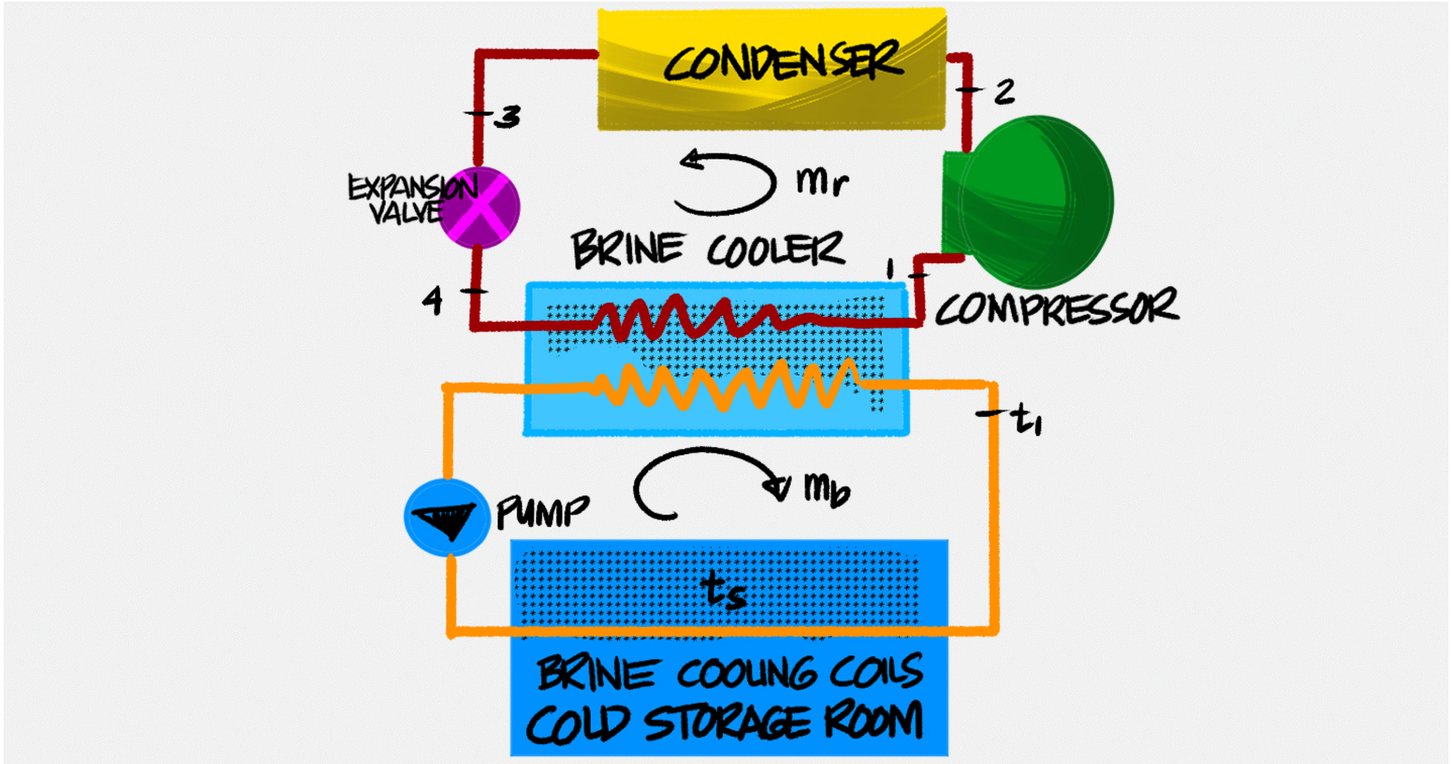
h_3 → h_g AT EVAP. TEMP.

ALSO:

$$mh_1 + Q_A = mh_2$$

m → MASS OF CHILLED H_2O

COLD STORAGE



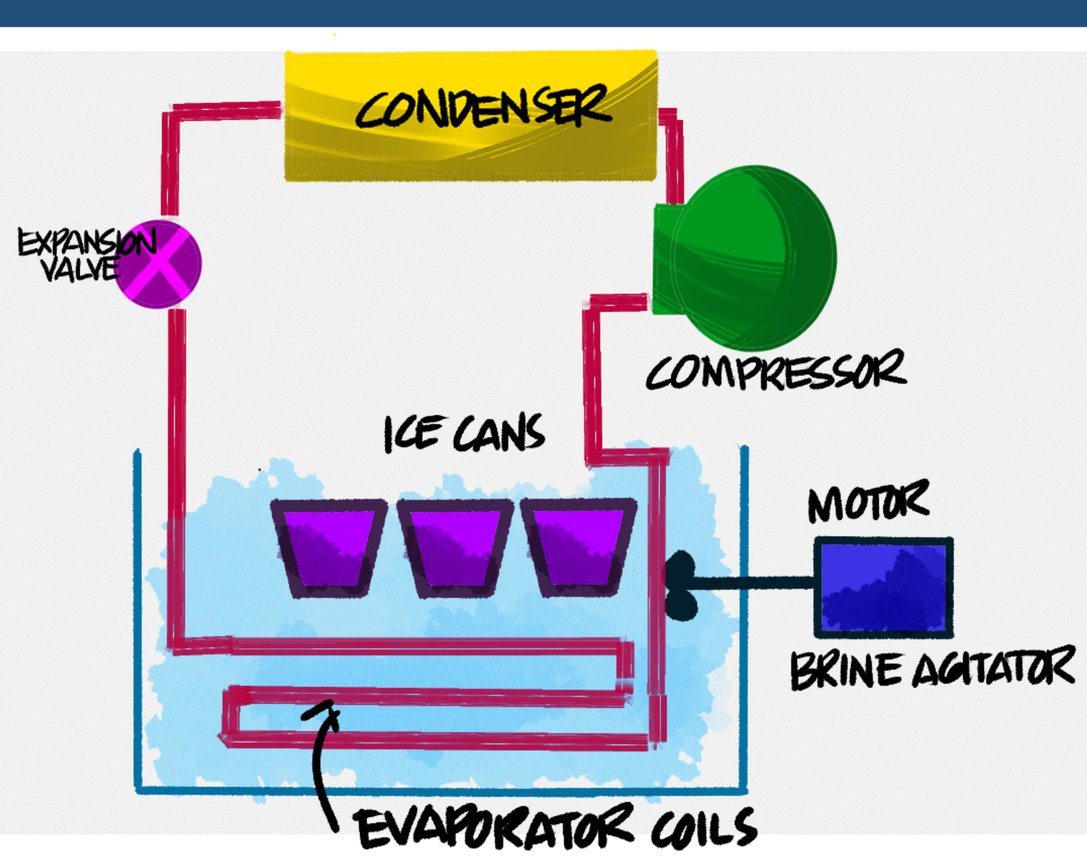
- **BRINE** – IS WATER PLUS SODIUM CHLORIDE AND/OR CALCIUM CHLORIDE MIXTURE WHOSE PURPOSE OF ADDITION OF IMPURITIES IS TO DECREASE THE FLUID FREEZING TEMPERATURE.
- **HEAT OF RESPIRATION (HR)** – APPLICABLE ONLY FOR FRUITS AND RESPIRATION

TOTAL HEAT LOAD

$$Q_{TOT} = mb\left[C_{bf}(t_1 - t_f) + L_f + C_{af}(t_f - t_s)\right] + mbHR$$

t_1 = TEMPERATURE ENTERING
t_s = STORAGE TEMPERATURE
HR = HEAT OF RESPIRATION

ICE PLANT



HEAT REMOVED FROM WATER TO MAKE ICE

$$Q = mr\left[C_{bf}(t_{wi} - t_f) + L_f + C_{af}(t_f - t_{if})\right]$$

C_{bf} & C_{af} → WATER SPECIFIC HEAT

t_{wi} → TEMP → WATER INITIAL

t_{if} → TEMP → ICE FINAL

ALLOWANCE OF HEAT LOSS

-USUALLY **10%-20%** OF THE HEAT REMOVED, USE HIGHER VALUE

$$Q_{TOTAL} = 1.2\,Q$$

EMPIRICAL EQUATION FOR FREEZING TIME

$$FT = \frac{CX^2}{32 - t_b}$$

C = EMPIRICAL CONS. 5.75 ~ 7 → USE 7.!!

t_b = BRINE TEMP., °F

X → AVERAGE OR MEAN THICKNESS OF ICE BLOCK (ICE CAKE), in.

IN PH, 300-lb BLOCK, X = 11 INCHES

NUMBER OF ICE CANS PER TON OF ICE, N

$$N = \frac{2000\,FT}{24\,W_{ICE}}$$

FT = FREEZING HOURS, hr.

W_{ICE} = WEIGHT OF ICE BLOCK, lbs.

REFRIGERANTS

- IS A SUBSTANCE USED IN REFRIGERATING MECHANISM. IT ABSORBS HEAT IN EVAPORATOR BY CHANGE OF STATE FROM LIQUID TO GAS.

TWO TYPES OF REFRIGERANTS

- **PRIMARY REF.**– REFRIGERANTS USED IN VAPOR-COMPRESSION SYSTEMS
- **SECONDARY REF.** – ARE LIQUIDS USED FOR **TRANSPORTING LOW-TEMPERATURE HEAT ENERGY** FROM ONE LOCATION TO ANOTHER. **ALSO CALLED ANTI-FREEZERS OR BRINES.**

PRIMARY REFRIGERANTS

HALOCARBON COMPOUNDS

- CONTAINS ONE OR MORE OF THE THREE HALOGENS – **CHLORINE, FLUORINE, BROMINE**
- STANDARDIZED BY **ASHRAE**

R-11	R-13	R-113
R-12	R-40	R-114

R-113
- → NUMBER OF FLUORINE ATOMS
- → HYDROGEN +1 (ATOMS)
- → CARBON – 1 (ATOMS)
- → STANDS FOR REFRIGERANT

INORGANIC COMPOUNDS

R-717	AMMONIA	NH_3
R-718	WATER	H_2O
R-729	AIR	$O_2 + 3.76N_2$
R-744	CARBON DIOXIDE	CO_2
R-764	SULFUR DIOXIDE	SO_2

EXAMPLE: R717 → 17 = MOLECULAR WEIGHT OF NH_3 → N=14(1), H=1(3) = 17

HYDROCARBONS

- SUITABLE REFRIGERANTS ESPECIALLY FOR SERVICE IN THE PETROLEUM AND PETROCHEMICAL INDUSTRY

R-50	METHANE	CH_4
R-170	ETHANE	C_2H_6
R-290	PROPANE	C_2H_3

EXAMPLE: R-170

FOR ETHANE (C_2H_6)
- 1 → CARBON -1 → 2-1 = 1
- 7 → HYDROGEN+1 → 6+1 = 7
- 0 → FLUORINE → 0 = 0

AZEOTROPES

- MIXTURE OF TWO DIFFERENT REFRIGEANTS

R-500	R12 (MIXTURE)	R-152a
R-502	R22	R-115
R-503	R23	R-13

EXPENDABLE REFRIGERANTS

- REFRIGERANTS USED TO COOL A SUBSTANCE OR EVAPORATOR AND THE REFRIGERATOR IS THEN RELEASED TO THE ATMOSPHERE

R-728	LIQUID NITROGEN
R-704	LIQUID HELIUM
R-744	CARBON DIOXIDE

GROUPINGS AND CLASSIFICATIONS OF REFRIGERANTS

- **NRSC** – NATIONAL REFRIGERATION SAFET CODE
  - GROUPS ONE TO THREE **(1-3)**
    - **GROUP 1** – SAFEST OF THE REFRIGERANTS
    - **GROUP 2** – TOXIC AND SOMEWHAT FLAMMABLE
    - **GROUP 3** – FLAMMABLE REFRIGERANTS
- **NBFU** – NATIONAL BOARD OF FIRE UNDERWRITERS
  - CLASS ONE TO SIX **(1-6)**
  - CLASS ONE IS MOST TOXIC WHILE CLASS SIX IS LEAST TOXIC

REFRIGERANT NO.	CYLINDER COLOR
R-11	ORANGE
R-113	PURPLE
R-114	DARK BLUE
R-123	SILVER
R-12	WHITE
R-22	GREEN
R-1349	SKYBLUE
R-500	YELLOW
R-502	ORCHID
R-717	SILVER
R-13	PALE BLUE
R-503	AQUAMARINE

SECONDARY REFRIGERANTS

COMMONLY USED SECONDARY REFRIGERANTS

- CALCIUM CHLORIDE
- SODIUM CHLORIDE
- ETHYLENE GLYCOL
- PROPYLENE GLYCOL

AIRCONDITIONING

THE **AUTOMATIC CONTROL OF AN ATMOSPHERIC ENVIRONMENT** EITHER FOR THE HUMAN/ANIMAL COMFORT OR FOR THE PROPER PERFORMANCE OF INDUSTRIAL/SCIENTIFIC PROCESS.

FUNCTIONS

- CONTROL THE TEMPERATURE
- CONTROL THE HUMIDITY
- CONTROL THE PURITY (REMOVAL OF DUST AND OTHERS)
- CONTROL OF AIR CIRCULATION/MOVEMENT

DEFINITION OF TERMS:

PSYCHROMETRY	STUDIES **THERMODYNAMIC PROPERTIES OF MOIST AIR** AND THE EFFECT OF MOISTURE ON MATERIALS AND HUMAN COMFORT.
PSYCHROMETRIC CHART	A GRAPHICAL REPRESENTATION OF THE THERMODYNAMIC PROPERTIES OF MOIST AIR, PROCESSES, AND CYCLES
PSYCHROMETER	INSTRUMENT USED TO STUDY THE PROPERTIES OF AIR

TYPES OF AIR

ATMOSPHERIC AIR	A MIXTURE OF GASES, WATER VAPOR, AND POLLUTANTS
SATURATED AIR	AIR WHERE ANY DECREASE IN TEMPERATURE WILL RESULT IN **CONDENSATION OF THE WATER VAPOR INTO LIQUID.**
UNSATURATED AIR	AIR CONTAINING **SUPERHEATED VAPOR.**
MOIST AIR	A BINARY **MIXTURE OF DRY AIR AND WATER VAPOR**
DRY AIR	A NON-CONDENSING COMPONENT, MAINLY **NITROGEN AND OXYGEN.**
VAPOR	CONDENSABLE COMPONENT OF THE MIXTURE

AIR ☑ DRY AIR – NITROGEN = 78% BY VOL.
OXYGEN = 21% BY VOL.
$CO_2 \approx 1\%$
☑ WATER VAPOR = 1% TO 3% DEPENDS ON WEATHER
$\rho = 0.075 \frac{lb}{ft^3}$ @ 70°F, 14.7psi

AIR CONDITIONING PROPERTIES

1. PRESSURE

$$P_t = P_a + P_v$$

P_t = TOTAL PRESSURE OF AIR-VAPOR MIXTURE
P_a = PARTIAL PRESSURE OF DRY AIR
P_v = PARTIAL PRESSURE OF WATER VAPOR

DALTON'S LAW OF PARTIAL PRESSURE – TOTAL PRESSURE OF ATMOSPHERIC AIR IS THE SUM OF THE PARTIAL PRESSURES OF DRY AIR AND WATER VAPOR.

APPROXIMATE FORMULA

$$T_{SAT}(°C) = \frac{237.7[\ln(1.638P_v)]}{17.27 - [\ln(1.638P_v)]}$$

T_{SAT} = TEMP. SAT. IN °C
P_v = VAPOR PRESSURE IN KPa

2. TEMPERATURE

DRY BULB TEMP. t_{DB}	• ACTUAL TEMP. OF AIR • MEASURED BY ORDINARY THERMOMETER
WET BULB TEMP. t_{WB}	• TEMPERATURE OF AIR IF IT'S SATURATED • MEASURED BY WETTED WICK THERMOMETER • TEMPERATURE OF ATM. AIR IN AN ADIABATIC PROCESS
WET BULB DEPRESSION	$WBD = t_{WB} - t_{DB}$
DEW POINT TEMP. t_{DP}	WATER VAPOR IN AIR CONDENSES (CONSTANT PRESSURE COOLING)

SLING PSYCHROMETER – MADE UP OF TWO THERMOMETERS, ONE DRY BULB AND ONE WET BULB SIDE BY SIDE.

3. SPECIFIC VOLUME

$$v = \frac{V_a}{m_a} = \frac{R_a T}{P_a} = \frac{R_a T}{P_t - P_v}$$

4. HUMIDITY RATIO

- RATIO OF THE MASS OF WATER VAPOR TO THE MASS OF DRY AIR

$$W = \frac{m_v}{m_a} = 0.622 \frac{P_v}{P_t - P_v}$$

$0.622 \hookrightarrow \frac{MW_{H_2O}}{MW_{AIR}} = \frac{18}{28.97}$

MASS OF WATER VAPOR IS USUALLY MEASURED IN GRAINS

$1lb = 7000$ GRAINS

5. RELATIVE HUMIDITY

$$RH = \frac{P_v}{P_{SAT}}$$

$P_{SAT} \rightarrow P_{SAT}$ @ DEWPOINT TEMP.
$P_{SAT} \rightarrow P_{SAT}$ @ DRY BULB TEMP.

6. ENTHALPY

$$h = c_p(t_{db}) + W h_g;$$

$h_g = h_g$ @ t_{db}
$h =$ in $\frac{KJ}{kg}$

APPROXIMATE FORMULA

$C_{PAIR} = 1.0 \frac{kJ}{kg\,K}$

$$h_g = 2500.9 + 1.82 t_{db_a}; \frac{KJ}{kg}$$

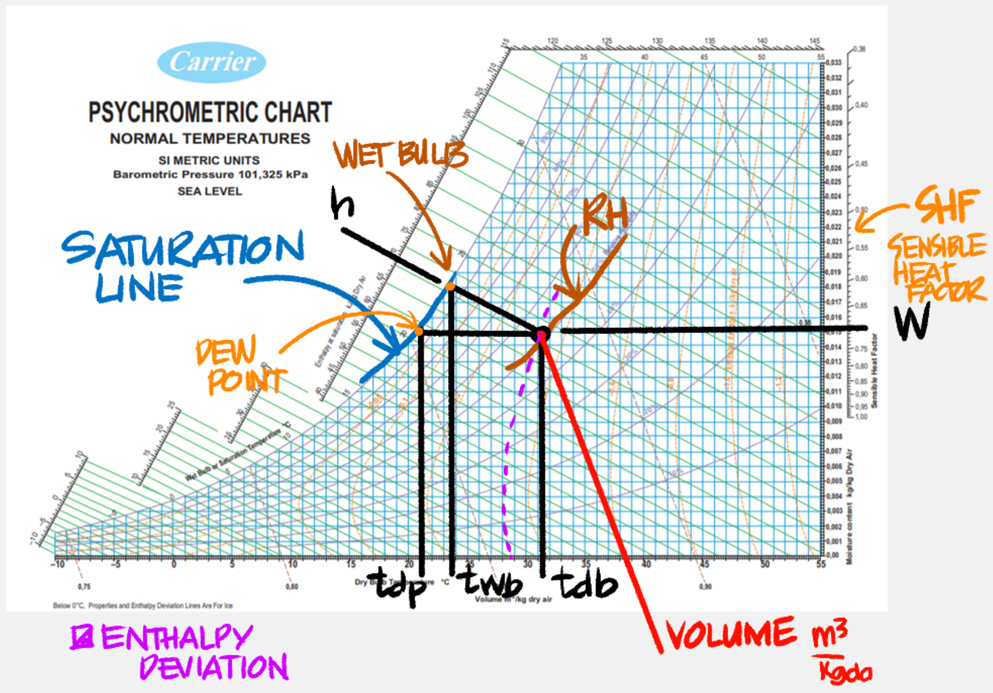
t_{db_a} ↳ °C

7. PERCENT SATURATION | DEGREE OF SATURATION | PERCENTAGE HUMIDITY

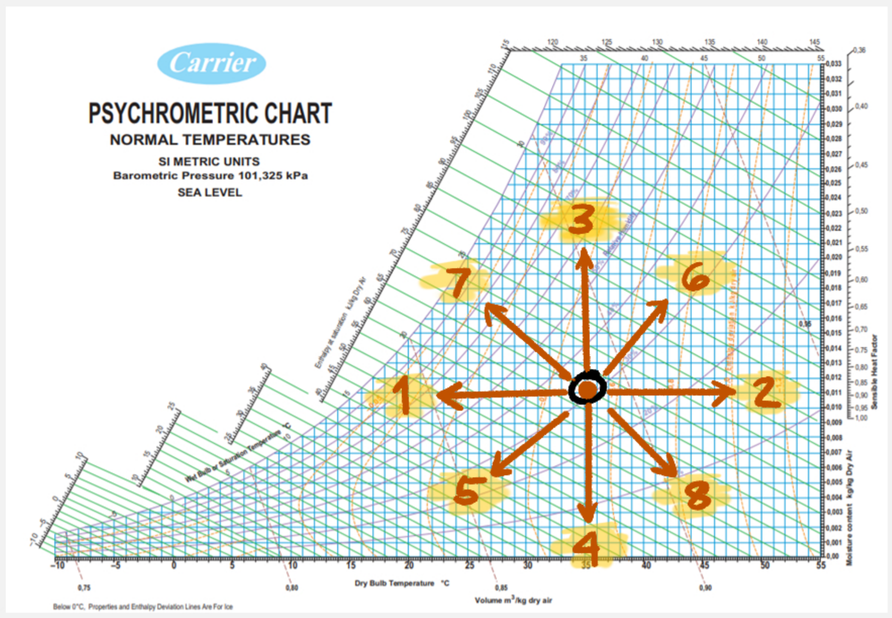
$$\%\ \text{SATURATION} = \frac{\text{ACTUAL HUMIDITY RATIO}}{\text{HUMIDITY RATIO OF SAT. AIR}}$$

$$\%\ \text{SATURATION} = RH\left[\frac{P_t - P_{SAT}}{P_t - P_v}\right]$$

PSYCHROMETRIC CHART



PROCESSES

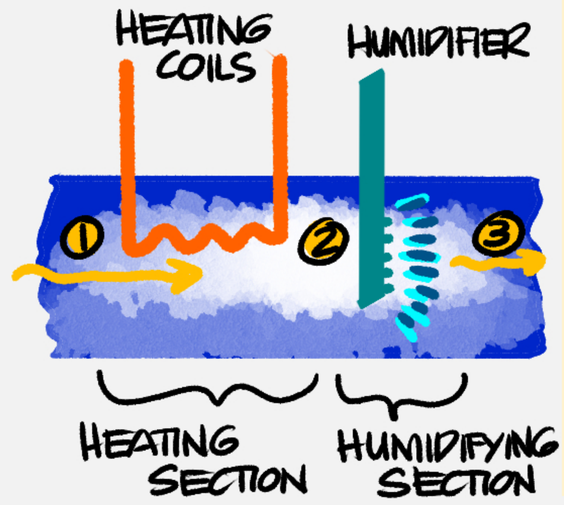


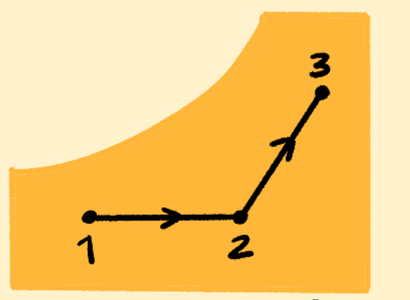
PSYCHROMETRIC PROCESSES

0-1	COOLING
0-2	HEATING (HEATER)
0-3	HUMIDIFYING (ISOTHERMAL DRYER)
0-4	DEHUMIDIFYING
0-5	COOLING & DEHUMIDIFYING (AIRCON)
0-6	HEATING & HUMIDIFYING (COOLING TOWER)
0-7	COOLING & HUMIDIFYING (ADIABATIC DRYER)
0-8	HEATING & DEHUMIDIFYING (CHEM'L DEHUMID.)

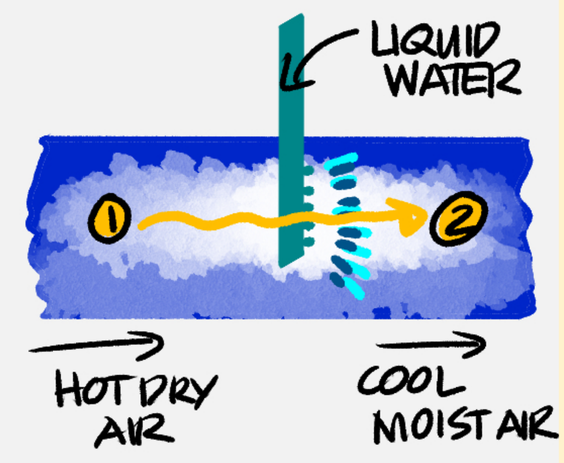
ENTHALPY DEVIATION – DIFFERENCE BETWEEN THE ACTUAL/TRUE SPECIFIC ENTHALPY AND THE SPECIFIC ENTHALPY OF SATURATED AIR AT GIVEN WET BULB TEMPERATURE.

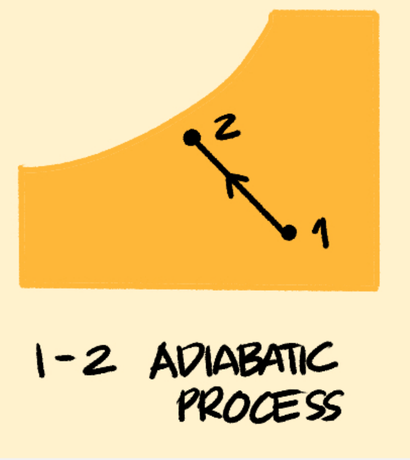
HEATING AND HUMDIFYING PROCESS



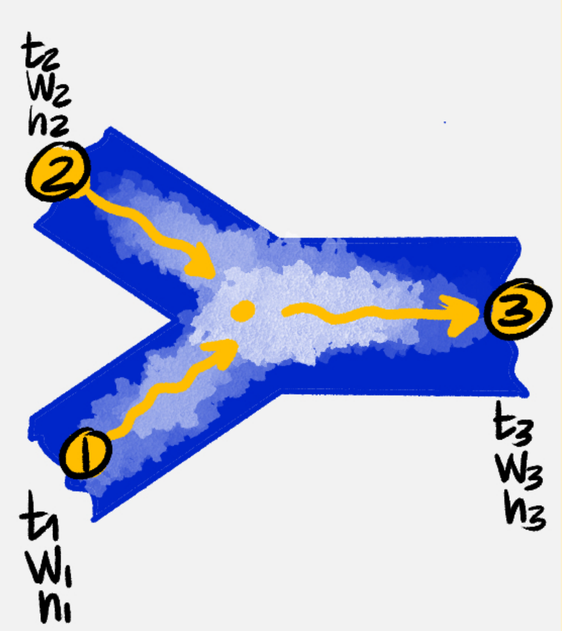


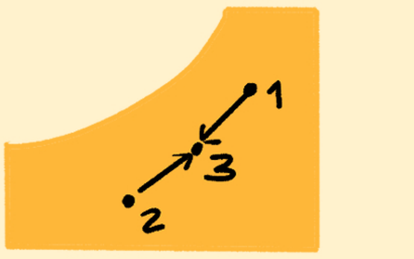
ADIABATIC PROCESS





AIR MIXING





- HEAT BALANCE
  $m_1h_1 + m_2h_2 = (m_1+m_2)h_3$
- MOISTURE BALANCE
  $W_1m_1 + W_2m_2 = (m_1+m_2)W_3$
- DRY BULB BALANCE
  $m_1t_1 + m_2t_2 = (m_1+m_2)t_3$

BYPASS FACTOR

THE PORTION OF THE AIR THAT PASSES THROUGH THE COIL WITHOUT CONTACTING THE COIL SURFACE.

BF OF HEATING COIL

$$BF = \frac{t_c - t_b}{t_c - t_a}$$

BF OF COOLING COIL

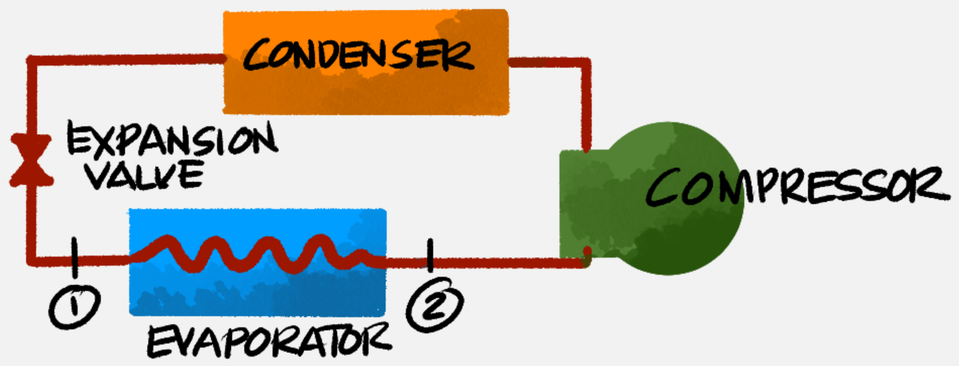
$$BF = \frac{t_b - t_c}{t_a - t_c}$$

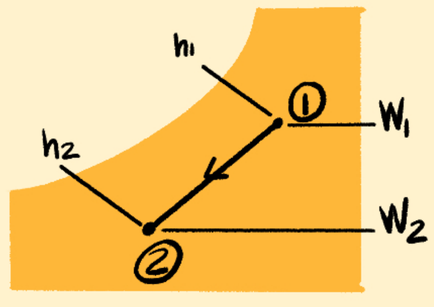
COIL FACTOR

$$CF = \frac{t_a - t_b}{t_a - t_c}$$

APPLICATIONS OF PSYCHROMETRY

AIR CONDITIONER





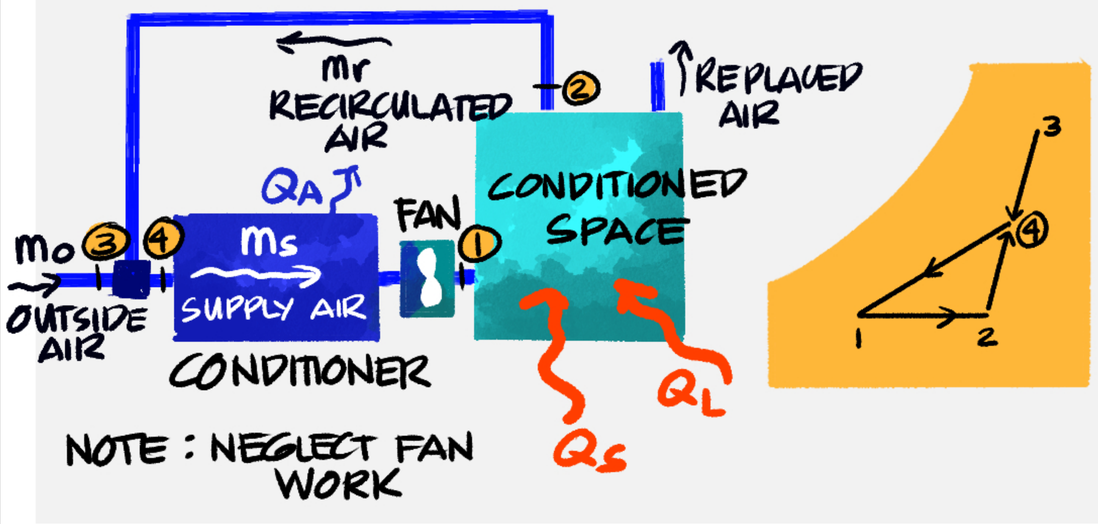
- LOWERS TEMP. & HUMIDITY OF AIR

$$q_L = m_a(h_1 - h_2)$$

RATE OF MOISTURE REMOVAL $= m_a(W_1 - W_2)$

$$V_a = m_a(v_1)$$

AIR CONDITIONING CALCULATIONS



SENSIBLE HEAT

$$Q_S = m_1 c_p (t_2 - t_1)$$

LATENT HEAT LOAD

$$Q_L = m_1 (W_2 - W_1) \times h_v$$

USE; $h_v = 2442 \frac{KJ}{kg}$

TOTAL HEAT LOAD

$$Q_T = Q_S + Q_L$$

SENSIBLE HEAT RATIO

$$SHR = \frac{Q_S}{Q_S + Q_L} = \frac{Q_S}{Q_T}$$

AIRCONDITIONING CAPACITY

$$m_s = m_r + m_o \longrightarrow m_o h_3 + m_r h_2 = m_s h_4$$

$$Q_{AIRCON} = m_s(h_4 - h_1)$$

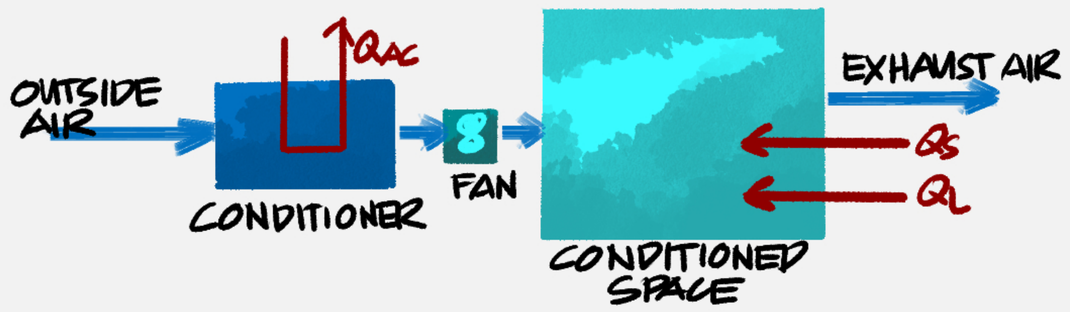
AIRCONDITIONING CAPACITY – NO MIXING PLENUM

$$Q_{AIRCON} = m_o(h_3 - h_1) + m_r(h_2 - h_1)$$

METHODS OF AIR HANDLING TO A CONDITIONED SPACE

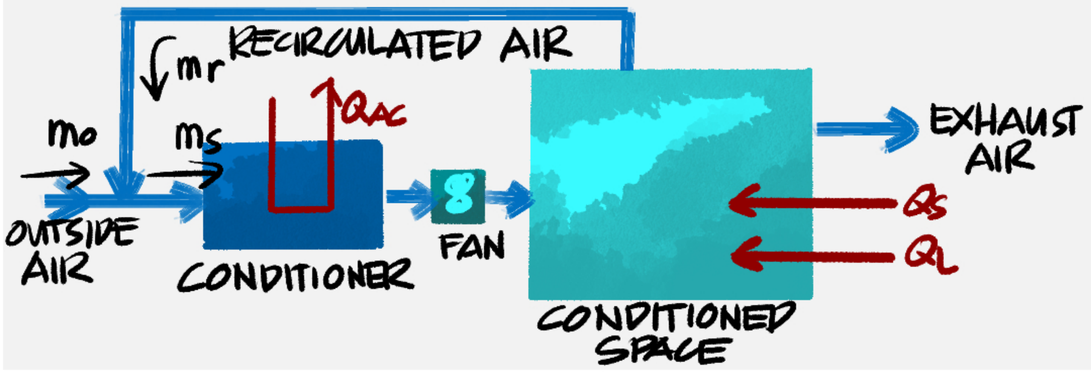
100% OUTSIDE AIR (FRESH AIR)

IN AREAS WHOSE OUTSIDE CONDITIONS ARE CLOSE IN TEMPERATURES AND HUMIDITY TO THE SPACE BEING MAINTAINED.



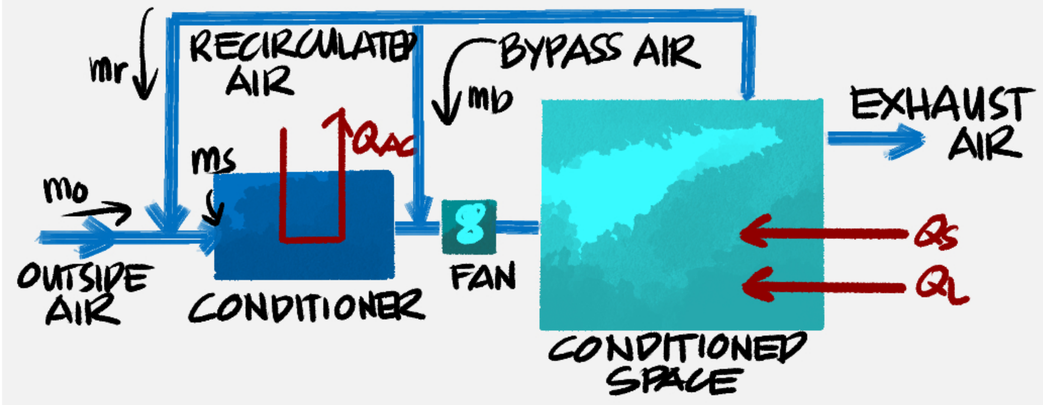
OUTSIDE AIR WITH RECIRCULATION

MORE ECONOMICAL THAN ALL OUTSIDE AIR, SINCE THE RECIRCULATED AIR TEMPERATURE IS CLOSER TO THE CONDITIONED SPACE; NOT FOR AREAS WHERE TOXIC ODORS ARISE.



OUTSIDE AIR WITH RECIRCULATION

PART OF THE RECIRCULATED AIR IS CONTROLLED BY DAMPER ACTION MAKING IT BYPASS THE CONDITIONER.



DEFINITION OF TERMS:

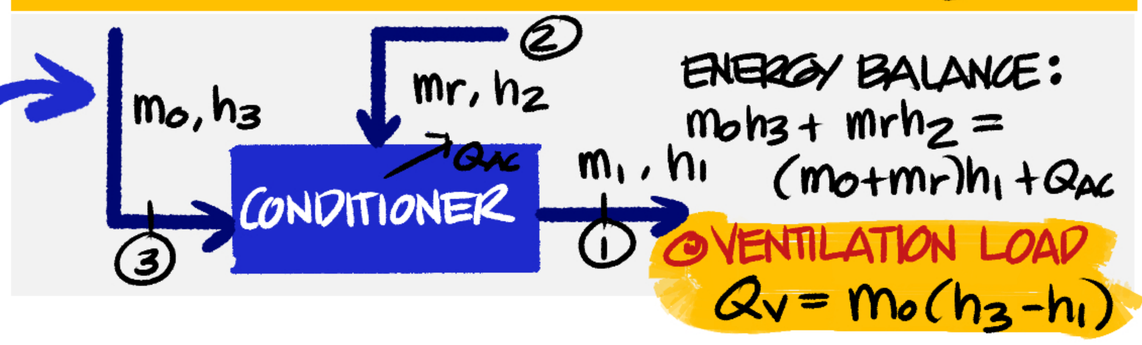
ROOM SENSIBLE HEAT FACTOR — RATIO OF **ROOM** SENSIBLE HEAT TO THE SUMMATION OF **ROOM** SENSIBLE AND **ROOM** LATENT HEAT

GRAND SENSIBLE HEAT FACTOR — RATIO OF THE TOTAL SENSIBLE HEAT TO THE **GRAND** TOTAL HEAT, **INCLUDING** THE **OUTDOOR AIR HEAT LOADS.**

EFFECTIVE ROOM SENSIBLE HEAT FACTOR — IS THE RATIO OF **EFFECTIVE** ROOM SENSIBLE HEAT TO THE **EFFECTIVE** TOTAL HEAT

CONVERSIONS:

$$1\ TOR = 12000 \frac{BTU}{hr} = 3.516\ KW = \frac{20{,}000}{3} \frac{CHU}{hr}$$

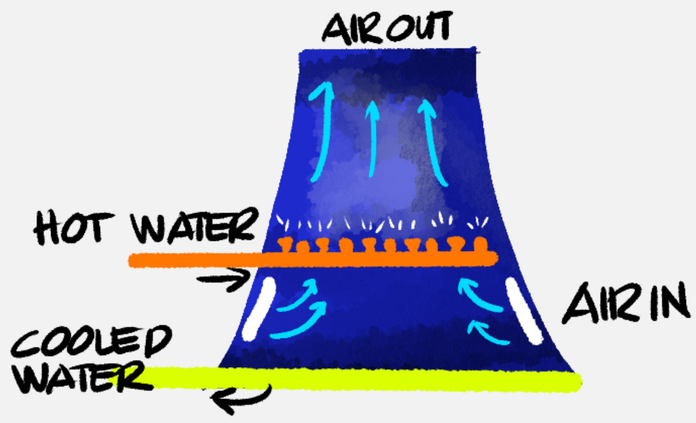


COOLING TOWERS

- REJECT HEAT BY **REDUCING THE TEMPERATURE OF WATER** CIRCULATED THROUGH CONDENSERS.
- RECIRCULATING WATER FROM A CONDENSER IS **EVAPORATIVELY COOLED BY CONTACT WITH ATMOSPHERIC AIR.**

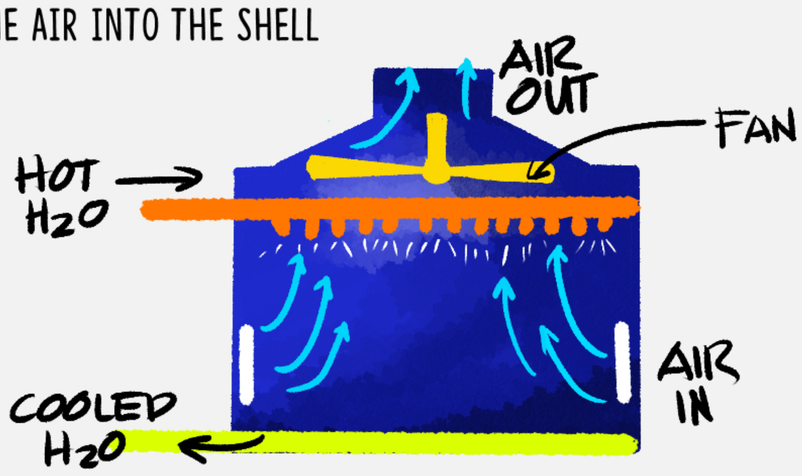
NATURAL-DRAFT TOWER | ATMOSPHERIC TOWER

CONDENSER WATER IS DISTRIBUTED AT THE TOP OF THE TOWER, INTO THE SHELL, THEN COLLECTED AT THE BASIN



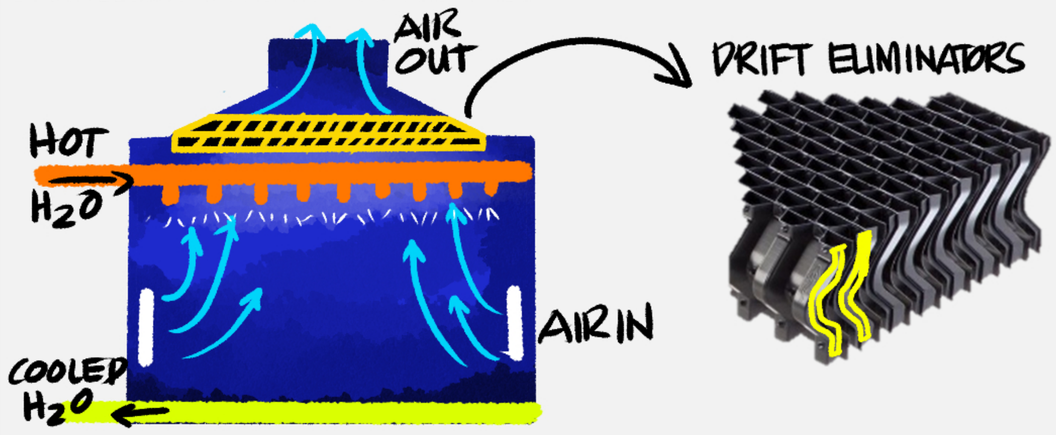
FORCED DRAFT TOWER

USES WATER EVAPORATION FOR COOLING. THE DIFFERENCE IS THAT A FAN PUSHES THE AIR INTO THE SHELL



INDUCED-DRAFT COOLING TOWERS

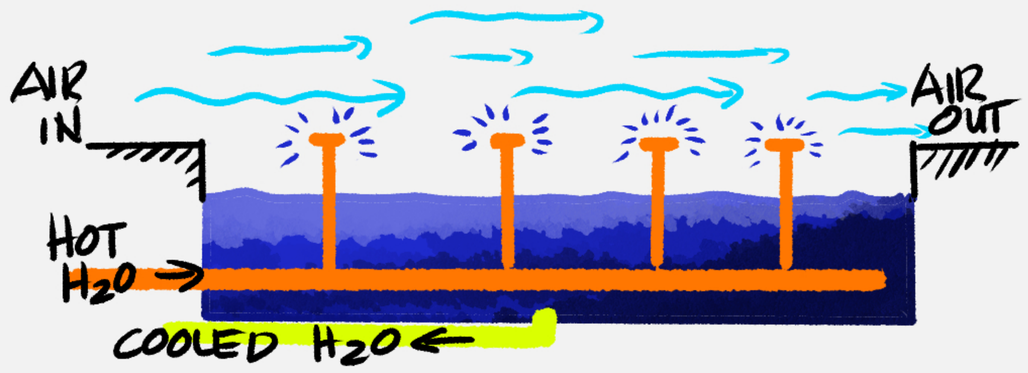
MOST POPULAR TOWERS USED IN THE CITIES. TWO OR MORE FANS INSTALLED ON THE TOP OF THE UNIT.



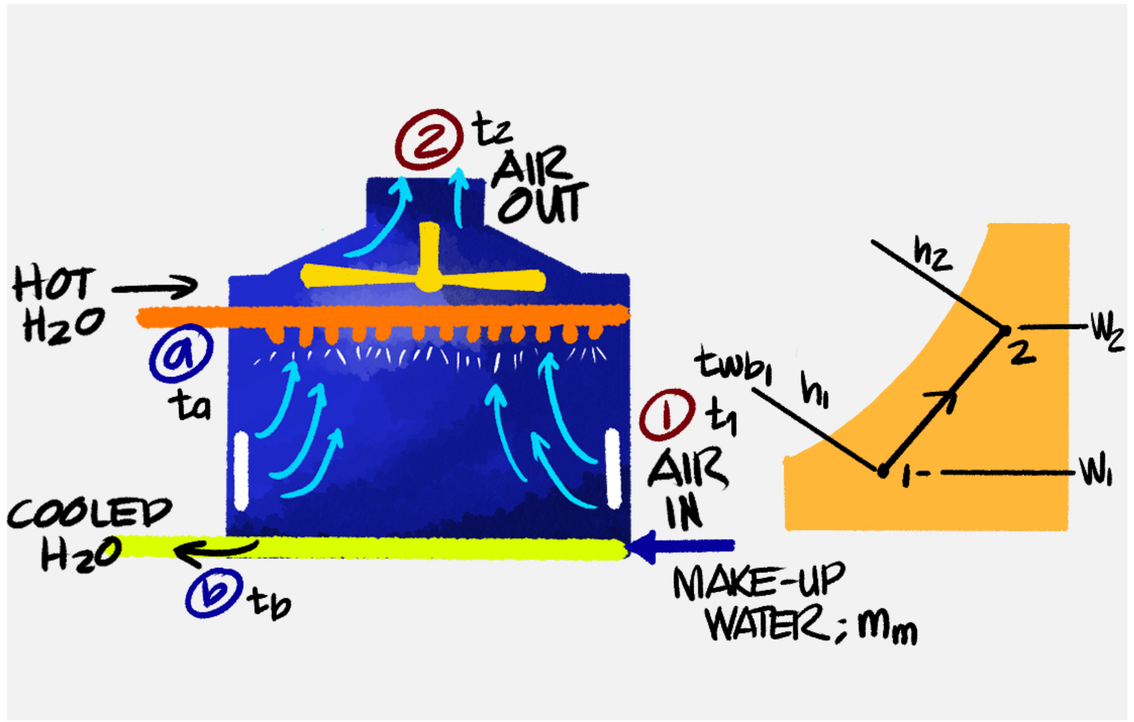
DRIFT ELIMINATORS - THE ELIMINATORS PREVENT THE WATER DROPLETS AND MIST FROM ESCAPING THE COOLING TOWER.

COOLING POND

A MAN-MADE BODY OF WATER FORMED FOR THE PURPOSE OF COOLING HEATED WATER TO A NEARBY POWER PLANT OR INDUSTRIAL FACILITY.



ANALYSIS:



RANGE t_R

TEMP. DIFFERENCE OF WATER ENTERING OR LEAVING THE TOWER

$$t_R = \text{RANGE} = t_a - t_b$$

APPROACH t_A

TEMP. DIFFERENCE OF WATER LEAVING THE TOWER AND WET BULB TEMP. OF ENTERING AIR

$$t_A = \text{APPROACH} = t_b - t_{WD_1}$$

RATE OF MOISTURE REMOVED | MAKE-UP WATER REQUIREMENT

$$\text{MOISTURE REMOVED} = m_1(W_2 - W_1) \quad \Big| \quad m_m = m_a - m_b, \quad \text{MOISTURE REMOVED} = m_m$$

HEAT BALANCE

$$q_a = q_w$$
$$m_1(h_2 - h_1) = m_a c_{pw}(t_a - t_b)$$

ENERGY BALANCE

$$m_1 h_1 + m_a h_a + m_m h_m = m_2 h_2 + m_b h_b$$

QUANTITY OF WATER LOST BY BLEED OFF

$$Q_B = f Q_W \Delta t_W (\%\ \text{BLEED})$$

$f = \frac{0.01}{10°F}$ → QUANTITY OF H_2O LOST BY BLEED-OFF

Δt_W = RANGE IN °F

COOLING TOWER SPECIFICATION

40 - 30 - 20 → MEANS $t_a = 40°C$, $t_b = 30°C$, $t_{wb_1} = 20°C$

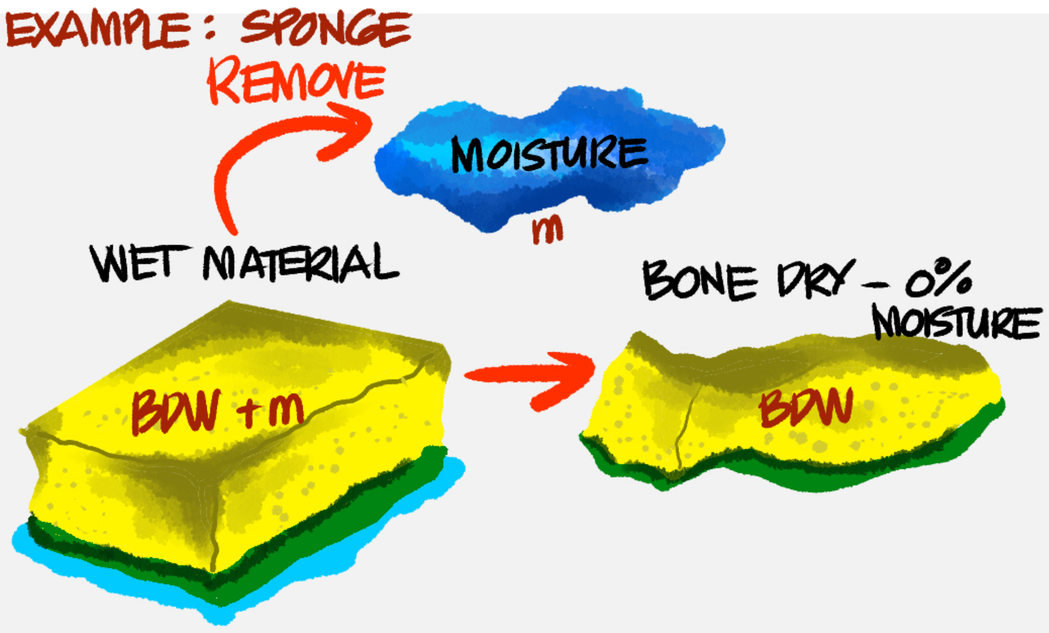
DRYERS

CLASSIFICATION OF DRYERS

ROTARY DRYER	• MOST COMMONLY USED DRYER • CONSISTS OF A **ROTATING CYLINDER** WHERE MATERIALS FLOW WHILE GETTING IN CONTACT WITH THE HOT GASES; THE CYLINDER IS TILTED AT A SLIGHT ANGLE • **COPRA, SAND, WOOD CHIPS**
TOWER DRYER	• WET FEED IS **INTRODUCED AT THE TOP AND FALLS DOWNWARD** WHILE COMING IN CONTACT WITH THE HOT AIR • **PALAY, WHEAT, GRAINS**
HEARTH DRYER	• MATERIAL TO BE DRIED IS **SUPPORTED ON A FLOOR** THROUGH WHICH THE HOT GASES PASS • **COPRA, COAL, ENAMEL WARES**
CENTRIFUGAL DRYER	• CENTRIFUGE REVOLVING AT HIGH SPEEDS CAUSING THE SEPARATION, BY CENTRIFUGAL FORCE, OF THE WATER FROM THE MATERIAL • **DRYING FERTILIZER, SALT, SUGAR**
TRAY DRYER	• TRAYS, CARRYING THE WET MATERIALS, **PLACED IN COMPARTMENT/ CONVEYOR** • **IPIL-IPIL LEAVES, GRAINS**
INFRARED RAY DRYER	• **INFRARED LAMPS** ARE DIRECTED TO THE ARTICLES TO BE DRIED • **DURING PAINTED ARTICLES LIKE CARS**
FREEZE-DRYING	• SUBLIMATION OF WATER VAPOR FROM ICE UNDER **HIGH VACUUM AT TEMP. BELOW 0** DEGREE CELSIUS.
DRUM DRYERS	• HEATED METAL ROLLS ON THE OUTSIDE OF WHICH **A THIN LAYER OF LIQUID IS DRYED.**

HYGROSCOPIC MATERIALS

ARE SUBSTANCES WHICH ARE **VARIABLE IN THE MOISTURE CONTENT** THEY CAN HOLD AT DIFFERENT TIMES.



BONE DRY WEIGHT

FINAL CONSTANT WEIGHT ATTAINED BY ANY HYGROSCOPIC SUBSTANCE AFTER BEING DRIED OUT.

GROSS WEIGHT

$$\text{GROSS WEIGHT } (W_T) = \Delta m + BDW$$

REGAIN

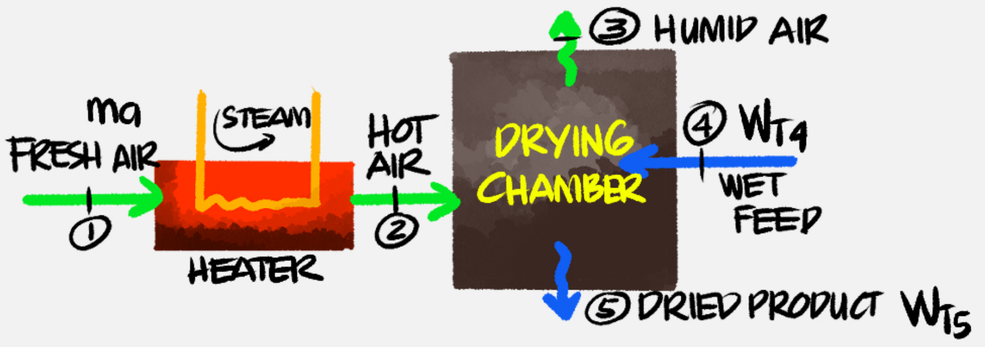
THE **HYGROSCOPIC MOISTURE CONTENT** OF A SUBSTANCE EXPRESSED AS THE RATIO OF THE MOISTURE WEIGHT TO THE BONE DRY WEIGHT.

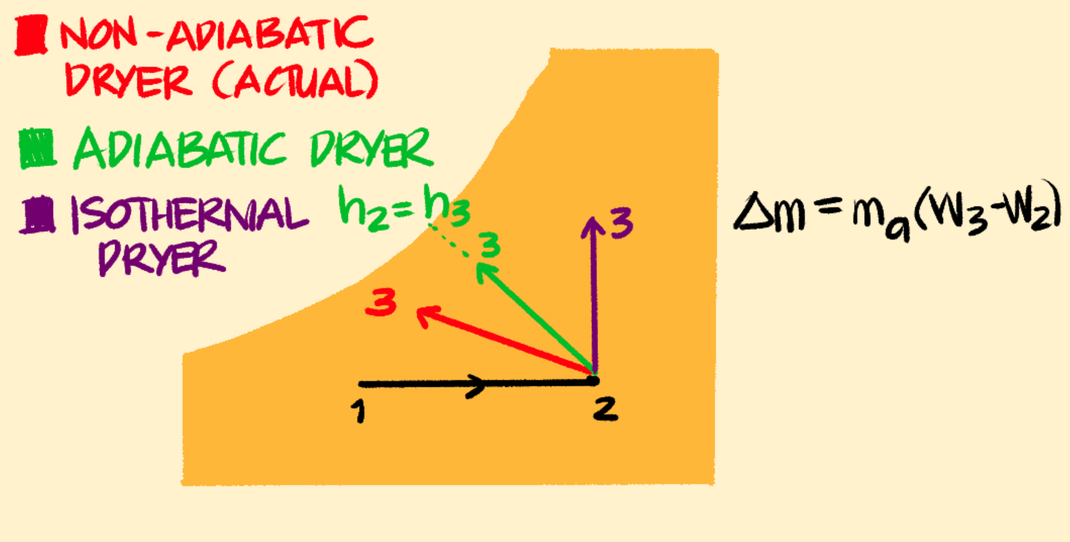
$$\text{REGAIN} = \frac{\text{MOISTURE WEIGHT}}{\text{BONE DRY WEIGHT}} = \frac{mf}{BDW}$$

MOISTURE CONTENT

$$\text{MOISTURE CONTENT} = \frac{\text{MOISTURE WT.}}{\text{GROSS WT.}} = \frac{mf}{W_T}$$

TYPICAL LAYOUT OF DRYING A PRODUCT





DRY BASIS

$$\%m_D = \frac{m_f}{BDM}$$ (m_f → MOISTURE)

WET BASIS

$$\%m_W = \frac{mf}{mf + BDM}$$ (mf + BDM → TOTAL MASS)

MOISTURE BALANCE

MATERIAL'S MOISTURE REMOVED = AIR'S MOIST. ADDED

$$W_{T4} - W_{T5} = ma(W_3 - W_2)$$

HEAT SUPPLIED IN THE HEATER

$$Q_a = ma(h_2 - h_1) \text{ ; kW}$$

EFFICIENCY

$$\text{EFFICIENCY OF DRYER} = \frac{\text{HEAT ABSORBED}}{\text{HEAT SUPPLIED}} = \frac{h_2 - h_3}{h_2 - h_1}$$

EVAPORATORS

ARE USED EITHER **TO REMOVE THE WATER FROM A LIQUID SUBSTANCE**, LIKE SUGAR JUICE, OR TO **PRODUCE DISTILLED WATER** BY CONDENSING THE STEAM.

TYPES OF EVAPORATORS (CONSTRUCTION)	
HORIZONTAL TUBE	• FOR NON-VISCOUS LIQUIDS THAT **DO NOT DEPOSIT SALT OR SCALE**
STANDARD VERTICAL TUBE	• FOR LIQUIDS THAT **DEPOSIT SALT OR SCALE** DURING EVAPORATION.
LONG TUBE, NATURAL-CIRCULATION VERTICAL EVAPORATOR	• CONSISTS OF LONG TUBES SO THAT THE **LIQUOR PASSES THROUGH THE EVAPORATOR BUT ONCE** • USED WITH NON-SALTING OR NON-SCALING LIQUIDS • CAN BE USED WITH HIGH VISCOSITIES • ONE OF THE CHEAPEST TYPES.
FILM TYPE	SPRAY OF WATER FALLS ON HIGH TEMPERATURE TUBES BECAUSE OF STEAM ON THE INSIDE.
SUBMERGED TYPE	WHERE THE **TUBE BUNDLE IS SUBMERGED IN THE LIQUID**

MULTIPLE EFFECT EVAPORATORS

- A SERIES OF EVAPORATORS SO CONNECTED THAT THE **VAPOR FROM ONE BODY IS USED AS THE HEATING STEAM** IN THE NEXT.

RELIEVING RATES

- THE **VELOCITY** AT WHICH THE **VAPOR LEAVES THE WATER SURFACE**

RELIEVING SURFACE

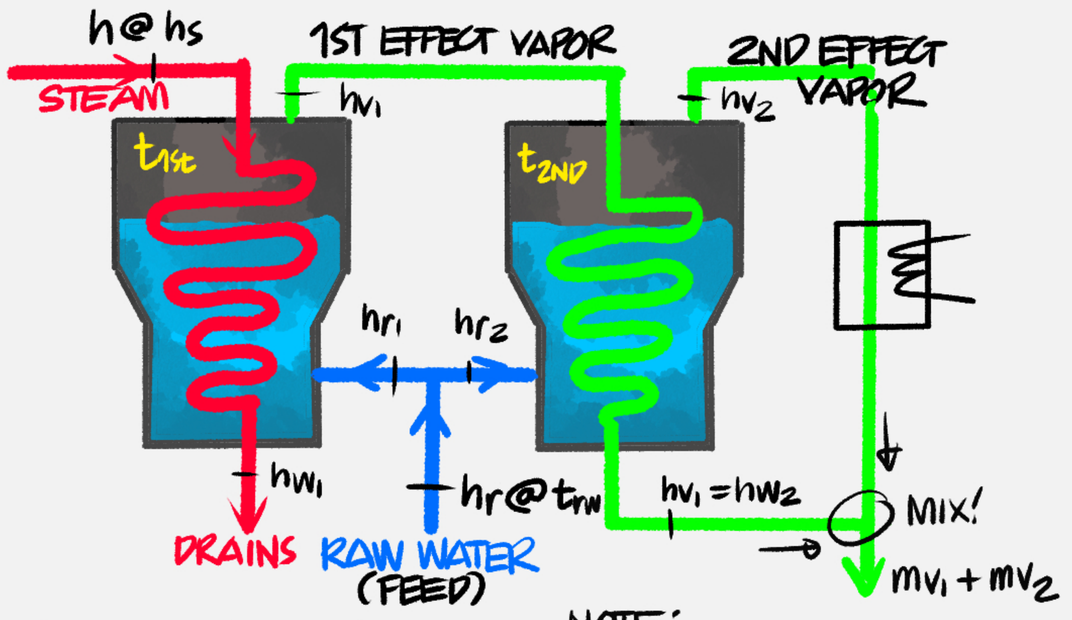
- THE **WIDTH OF THE WATER SURFACE** IN THE SHELL MULTIPLIED BY THE **DISTANCE BETWEEN THE TUBE SHEETS**

$$\text{DISENGAGING AREA / RELIEVING SURFACE} = \frac{\left(\frac{\text{WEIGHT OF VAPOR}}{\text{sec}}\right) \times \text{SPEC. VOLUME}}{\text{VELOCITY}}$$

HEAT HEAD

- DIFFERENCE BETWEEN THE **SATURATION TEMPERATURE OF THE MOTIVATING FLUID** AND THE **SATURATION TEMPERATURE OF THE VAPOR**

ANALYSIS: DOUBLE EFFECT EVAPORATORS



MASS BALANCE ON FIRST EFFECT

$$m_s h_s + m_{rw} h_{r_1} = m_{v_1} h_{v_1} + m_{w_1} h_{w_1}$$

BUT; $m_s = m_{w_1}$, $m_{v_1} = m_{rw}$

$$m_{v_1} = \frac{m_s (h_s - h_{w_1})}{h_{v_1} - h_{r_1}}$$

MASS BALANCE ON 2ND EFFECT

$$m_{v_1} h_{v_1} + m_{rw_2} h_{r_2} = m_{v_2} h_{v_2} + m_{w_2} h_{w_2}$$

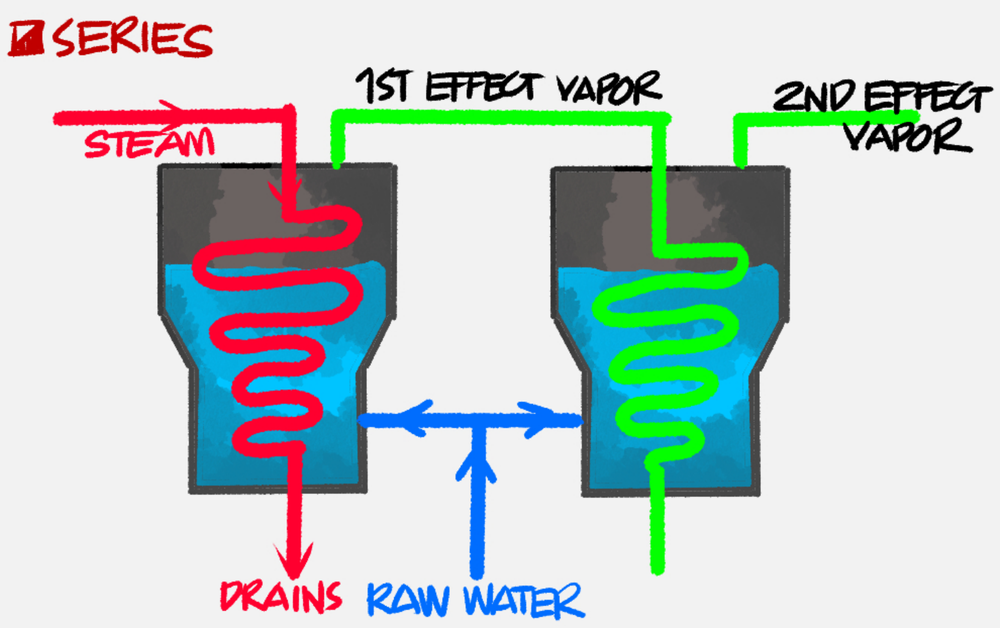
BUT; $m_{v_1} = m_{w_2}$, $m_{v_2} = m_{rw_2}$

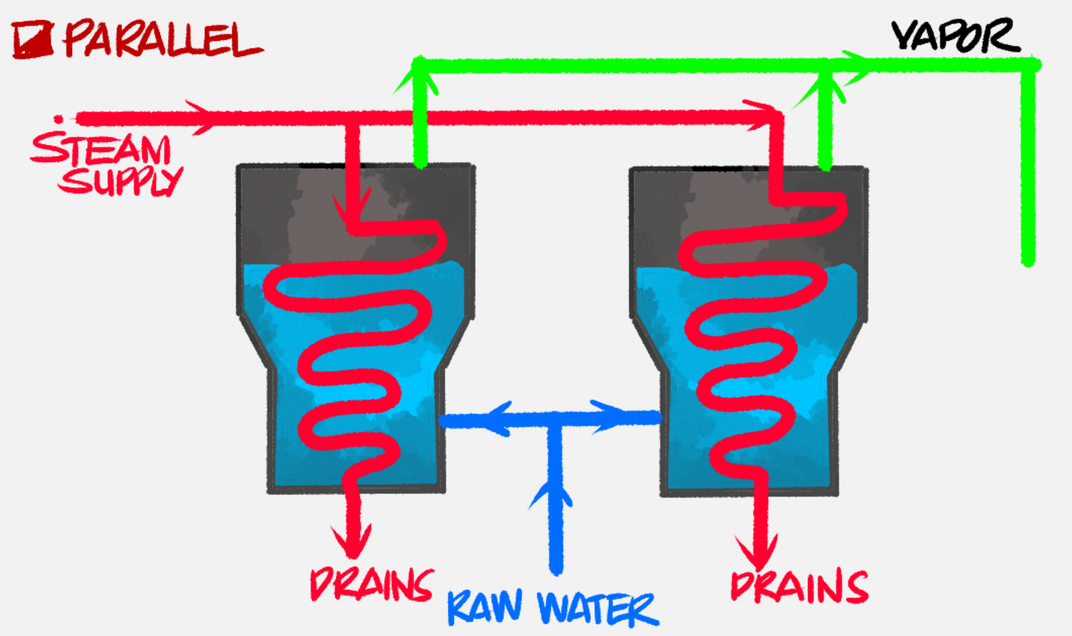
$$m_{v_2} = \frac{m_{v_1} (h_{v_1} - h_{w_2})}{h_{v_2} - h_{r_2}}$$

EVAPORATOR ECONOMY

$$\text{EVAPORATOR ECONOMY} = \frac{\text{TOTAL VAPOR PRODUCED}}{\text{STEAM SUPPLIED}} = \frac{m_{v_1} + m_{v_2}}{m_s}$$

EVAPORATOR ARRANGEMENT





CONVEYORS

EITHER FIXED OR PORTABLE DEVICES FOR MOVING MATERIALS BETWEEN TWO POINTS AT THE SAME OR DIFFERENT ELEVATIONS, WITH CONTINUOUS OR INTERMITTENT FORWARD MOVEMENT

TYPES OF CONVEYORS	
BELT	• CONTINUOUS SYSTEM; BELT **USUALLY TROUGHED** • HIGH CAPACITIES POSSIBLE • COAL, COPRA, OARS, PACKAGES
SPIRAL	• ENDLESS **HELICOIDS SCREW IN A TROUGH**
SCREW	• PULVERIZED COAL, FLOUR, GRAINS
FLIGHT / SCRAPER	• LOW IN FIRST COST BUT LARGE ENERGY CONSUMPTION. CONSIDERABLE **WEAR, CAUSED BY ABRASION** • SERIES OF **METAL FLIGHTS ATTACHED AT INTERVALS TO CHAIN** • PACKAGES, BOXES, COPRA
PIVOTED BUCK CARRIERS	• MATERIAL IS CARRIED AND BUCKETS ARE SUPPORTED ON ROLLERS • THE **PIVOTED BUCKET** CARRIES CAN **BOTH ELEVATE AND CONVEY.** • COPRA, COAL, GRAINS
LARRIES	• **SUSPENDED RAIL TYPES** ARE GENERALLY USED • THEY LEAVE THE BOILER AISLE FREE FROM OBSTRUCTION

BELT CONVEYORS

- COMMONLY USED, FIRST COST IS REASONABLE AND LOW POWER CONSUMPTION. WIDELY USED FOR HORIZONTAL MOVEMENT OF COALS

POWER

P_T = TOTAL CHAIN PULL

$P_T = P_1 + P_2 + P_3$

POWER = TOTAL CHAIN PULL × VELOCITY

P_1 = FORCE TO MOVE WEIGHT OF MATLS

P_2 = FORCE TO MOVE CONVEYOR PARTS ON LOADED RUN

P_3 = FORCE TO MOVE CONVEYOR PARTS ON EMPTY RUN

SCREW CONVEYORS DESIGN CONSIDERATION

- SCREW CONVEYORS SHALL BE GUARDED TO **PREVENT PERSONNEL FROM COMING INTO CONTACT WITH THE SCREW**. GUARDS OF **HORIZONTAL BARS** SPACED TO ALLOW MATERIAL TO BE FED INTO THE CONVEYOR SHALL BE NOT MORE THAN **2,440 MM** APART.
- **2,100 MM** OR LESS ABOVE FLOOR OR OTHER WORKING LEVEL SHALL BE COMPLETELY **COVERED WITH SUBSTANTIAL LIDS.**
- **600 MM** OR LESS ABOVE THE FLOOR MAY BE GUARDED BY **STANDARD RAILING GUARDS** OR **SUBSTANTIAL COVERS** OR **GRATINGS.**

CRANES AND HOISTING EQUIPMENT

BOOM	**TELESCOPIC** OR **FIXED** ARM. USED TO **MOVE** OBJECTS
BUFFER	CUSHIONING DEVICE, **MINIMIZE** SHOCK OF COLLISION
BUMPER	**STOPS** THE MOVING PART AT THE LIMIT OF TRAVEL OF A CRANE. PREVENTS MOTION BEYOND A POINT
CAB	HOUSES THE OPERATOR, HOISTING MECHANISM, AND EQUIPMENT CONTROLLING THE CRANE
CAGE	HOUSES THE OPERATOR, AND EQUIPMENT CONTROLLING THE CRANE

CRANES

- A MACHINE FOR **LIFTING OR LOWERING A LOAD** AND **MOVING IT HORIZONTALLY**

TYPES OF CRANES	
OVERHEAD TRAVELING/ BRIDGE CRANE	• ON A PAIR OF PARALLEL ELEVATED RUNWAYS, LIFTS AND LOWERS A LOAD AND CARRY IT **HORIZONTALLY PARALLEL TO, OR AT RIGHT ANGLES TO** • ITS OPERATION LIMITED TO THE AREA BETWEEN THE RUNWAYS. • **MAINTENANCE SHOPS, ICE PLANTS**
DERRICK CRANE	• FOR HOISTING, **DOES NOT INCLUDE A HOISTWAY NOR A CAR OR PLATFORM** TRAVELING THROUGH GUIDES • **LOADING IN SHIPS, HANDLING MATERIALS IN SHIPS**
JIB CRANE	• FIXED CRANE, SUPPORTED BY **A VERTICAL MEMBER FROM WHICH EXTENDS HORIZONTAL SWINGING ARMS CARRYING A TROLLEY HOIST** • **CONSTRUCTION WORKS, MAINTENANCE SHOPS**
GANTRY CRANE	• SIMILAR TO AN OVERHEAD TRAVELING, EXPECT THAT THE BRIDGE FOR CARRYING THE **TROLLEYS IS SUPPORTED ON TWO OR MORE MOVABLE LEGS** • **MINING, PIERS**
PILLAR CRANE	• FIXED CRANE, VERTICAL MEMBER HELD AT THE BASE, WITH **HORIZONTAL REVOLVING ARM CARRYING A TROLLEY** • **MAINTENANCE SHOPS, PIERS**

JIB

- **A HORIZONTAL ARM**, FOR SUPPORTING A TROLLEY OR FALL BLOCK. ARM EXTENSION OF THE HEAD OF THE BOOM

TROLLEY

- A TRUCK OR CARRIAGE ON WHICH THE **HOISTING MECHANISM IS MOUNTED** AND WHICH **TRAVELS ON AN OVERHEAD BEAM OR TRACK**

HOISTS - RAISING OR LOWERING A LOAD BY A VERTICAL PULLING FORCE, BUT **DOES NOT INCLUDE A CAR OR PLATFORM**

PIPING

PIPE – IS A **TUBE WITH A ROUND CROSS SECTION** CONFORMING TO THE DIMENSIONAL REQUIREMENTS FOR NOMINAL PIPE SIZE AS TABULATED IN TABLE FOR PIPE SCHEDULES.

BLACK PIPE	• STEEL PIPE THAT **HAS NOT BEEN GALVANIZED**
CARBON STEEL PIPE	• STEEL PIPE WITH PROPERTIES CHIEFLY OF CARBON
GALVANIZED PIPE	• COATED WITH ZINC TO RESIST CORROSION
WROUGHT PIPE	• REFERS **TO BOTH WROUGHT STEEL AND WROUGHT IRON. WROUGHT IN THIS SENSE MEANS WORKED.**
BELL AND SPIGOT JOINT	• COMMONLY USED JOINT IN CAST-IRON PIPE • EACH PIECE IS MADE WITH ENLARGED **DIAMETER OR *BELL*** AT ONE END INTO WHICH THE **PLAIN OR SPIGOT** END OF ANOTHER PIECE IS INSERTED • JOINT IS THEN TIGHTENED BY **CEMENT, OAKUM, LEAD OR RUBBER.**
BUTT WELD JOINT	• WELDED PIPE JOINT. WHERE ENDS OF THE TWO **PIPES BUTTING EACH OTHER** (AROUND PERIPHERY)
COMPRESSION JOINT	• A MULTI-PIECE JOINT WITH **CUP SHAPED THREADED NUTS.** WHEN TIGHTENED **COMPRESS TAPERED SLEEVES SO THAT THEY FORM JOINT** (PERIPHERY)
SOCKET WELD	• USE OF A **SOCKET WELD FITTING** WHICH HAS A **PREPARED FEMALE END** OR SOCKET FOR INSERTION OF THE PIPE THEN WELDED.
BULL HEAD TEA	• BRANCH OF WHICH IS LARGER THAN THE RUN
HEADER	• **LARGE PIPE OR DRUM** WHERE EACH OF A **GROUP OF BOILERS IS CONNECTED**
MANIFOLD	• FITTING WITH BRANCHES IN LINE CONNECTING TO A SMALLER PIPES • AN **INTERCHANGEABLE TERM WITH HEADER**
CROSS-OVER	• WITH DOUBLE OFFSET, OR **U – SHAPED** WITH ENDS TURNED OUT.
EXPANSION LOOP	• **LARGE RADIUS BEND** IN A PIPE LINE TO PREVENT EXPANSION IN THE PIPE LINE DUE TO HEAT
STREET ELBOW	• **MALE AND FEMALE THREAD** ON EACH ENDS
SADDLE FLANGE	• FLANGE **CURVED TO FIT A BOILER/TANK** AND ATTACHED TO A THREADED PIPE. RIVETED/WELDED TO BOILER/TANK.
CHECK VALVE	• SO THE FLUID TO **PASS IN ONE DIRECTION ONLY**
GATE VALVE	• **ALLOWS FLUID TO FLOW WHEN THE GATE IS LIFTED FROM THE SEAT.** LESS RESISTANCE TO FLOW THAN GLOBE VALVES.
GLOBE VALVE	• GLOBE SHAPED BODY WHICH WHEN CLOSED RESTS **ON A SEAT SO AS TO PREVENT PASSAGE OF A FLUID**
RELIEF VALVE	• OPEN AUTOMATICALLY TO RELIEVE EXCESS PRESSURE

MEDIUM PRESSURE FITTINGS, VALVES, & ETC.

WORKING PRESSURE: 862 - 1207 kPa (125-175 psi)

STANDARD PRESSURE CAST IRON FLANGES, FITTINGS, VALVES, & ETC.

MAX. STEAM WORKING PRESSURE = 862 kPa

MILL LENGTH

- ALSO KNOWN AS **RANDOM LENGTH**

RUN-OFF MILL PIPE : 4,880 mm – 6000 mm
SOME ARE MADE W/ DOUBLE LENGTHS : 9,150 mm – 10,675 mm

FLUID FLOW VELOCITIES

WATER	1.5 - 3 m/s
HIGH PRESSURE SAT. STEAM	25 - 50 m/s
HIGH PRESSURE SUPERHEATED STEAM	50 - 77 m/s
ATMOSPHERIC EXHAUST STEAM	40 - 60 m/s
LOW PRESSURE EXHAUST STEAM	100 - 120 m/s

IDENTIFICATION COLOR FOR PIPES

WATER	GREEN
STEAM	SILVER-GRAY
OIL-MINERAL (VEGETABLE/ANIMAL)	BROWN
GASES (GASES/LIQUID FORM), FUMES	YELLOW OCRE
ACID AND ALKALIS	VIOLET
AIR	LIGHT BLUE
OTHER FLUIDS, DRAINAGE	BLACK
FIRE FIGHTING MATERIALS	SAFETY RED
HAZARDOUS SERVICES	SAFETY YELLOW
ELECTRICITY	LIGHT ORANGE
COMMUNICATIONS	WHITE

SCHEDULE NUMBER

$$\text{SCHED. NO.} \approx \frac{1000 \times P}{S}$$

P = GAGE PRESSURE
S = WORKING STRESS

PIPE WALL THICKNESS FOR POWER PIPING SYSTEM

$$t_m = \frac{PD}{2S + yP} + C$$

t_m = MIN. PIPE WALL THCK.; mm
P = MAX. INTERNAL SERVICE PRESS.; kPa
D = OUTSIDE Ø; mm
S = ALLOWABLE STRESS; kPa
C = ALLOWANCE FOR THREADING, etc.; mm.

Y = COEFFICIENT
FOR REFRIG. PIPING SYS.:
USE Y = 0.8

NOTE:
NOMINAL THCK. $= \frac{8}{7} \times t_m$
SUBJECT TO 12.5° VARIATION

COMMERCIAL PIPING	
CAST IRON	• USED FOR **DRAINAGE** • RESISTANT TO CORROSION AND ABRASION.
WROUGHT STEEL	• MOST **POWER PLANT PIPING** • LOW-COST AND STRONG.
ALLOY STEELS	• OWE THEIR SPECIAL PROPERTIES TO ALLOYING ELEMENTS OTHER THAN CARBON
WROUGHT IRON	• TWO-COMPONENT METAL CONSISTING OF IRON ADDED WITH **1% TO 3%** OF FINELY DIVIDED AND UNIFORMLY DISTRIBUTED **IRON SILICATE**.
COPPER AND BRASS	• USED WHERE FLEXIBILITY, APPEARANCE, OR CORROSION RESISTANT IS IMPORTANT. HOWEVER, **COSTLY**.

PIPE CONNECTIONS (JOINTS)

PACKED	LEADED BELL-AND-SPIGOT, PLAIN AND COUPLING
SCREWED	COUPLINGS AND UNIONS
FLANGED	COMPANION FLANGES (LOOSE OR SCREWED), SHRUNK, RIVETED, OR WELDED TO PIPE
WELDED	FUSION PROCESS USING GAS OR METAL ARC WELDERS

SPECIAL VALVES

- **SAFETY VALVES** –BOILER SAFETY VALVES, THE ULTIMATE LINE OF **DEFENSE AGAINST THE OCCURRENCE OF HAZARDOUS STEAM PRESSURES IN THE BOILER**.
- **RELIEF VALVES** –A FORM OF SAFETY VALVE, BUT **USUALLY INTENDED FOR LESS SEVERE SERVICE**.
- **BLOW-OFF VALVES** –TO **RID THE MUD DRUMS OF SEDIMENT ACCUMULATIONS**, TO **DRAIN THE AND REDUCE CONCENTRATION** OF BOILER, AND TO **RAPIDLY LOWER THE BOILER WATER LEVEL**.
- **CONTROL AND REGULATING VALVES** – ARE FOR WATER LEVEL, STEAM PRESSURE, WATER FLOW, ETC. (THERMOSTATICALLY OR MECHANICALLY CONTROLLED)
- **BOILER OUTLET VALVES** –STOP-CHECK OR AUTOMATIC NON-RETURN TYPE. **TO PREVENT BOILERS IN PARALLEL RECEIVING BACKFLOW FROM THE OTHERS** WHEN ITS PRESSURE BECOMES SUBSTANDARD.

TYPES OF STEAM TRAPS	
CONTINUOUS FLOATS	FLOAT-OPERATED VALVE, SIMPLE IN PRINCIPLE AND OPERATION.
INTERMITTENT FLOATS	THE BUCKET TRAP IS A WELL-KNOWN EXAMPLE
UPRIGHT BUCKET	FLOATS ON THE INCOMING CONDENSATION AND **HOLDS THE DISCHARGE VALVE CLOSED** UNTIL THE **WATER RISES IN THE TRAP BODY** FAR ENOUGH TO SPILL INTO THE BUCKET.
INVERTED BUCKET	VENTS **BOTH THE CONDENSATE AND AIR THROUGH THE MAIN VALVE**
THERMOSTATIC	USES **TEMPERATURE-SENSITIVE ELEMENT** TO DETECT WHETHER **STEAM OR CONDENSATE SURROUNDS IT**
EXPANSION, ORIFICE TRAPS	HAVE A **FLASH CHAMBER**, OR **EXPANSION CHAMBER**, BETWEEN TWO RESTRICTIONS IN THE FLOW LINE.

FIRE PROTECTION SYSTEM

FIRE PROTECTION ENGINEERING – INVOLVES DESIGNING DEVICES, SYSTEMS AND PROCESSES TO PROTECT PEOPLE, PROPERTY AND BUSINESS OPERATIONS FROM THE RESULTS OF FIRE.

COMMODITY CLASSIFICATION

CLASS 1 METAL PRODUCTS, FOODS	ESSENTIALLY **NON COMBUSTIBLE PRODUCT ON WOOD PALLETS**, OR IN ORDINARY CARTONS, OR IN ORDINARY PAPER WRAPPING, ALL ON WOOD PALLETS
CLASS 2 INCANDESCENT LAMPS BEER/WINE UP TO **20** PERCENT ALCOHOL	PRODUCTS **IN SLATTED WOODEN CRATES**, SOLID WOODEN BOXES, OR EQUIVALENT COMBUSTIBLE PACKAGING MATERIALS ON WOOD PALLETS.
CLASS 3 WOOD DRESSED WITH PLASTIC DRAWERS, ETC.	**WOOD, PAPER, NATURAL FIBER CLOTH, PLASTIC PRODUCTS ON WOOD PALLETS**, PRODUCTS MAY CONTAIN A LIMITED AMOUNT OF PLASTICS.
CLASS 4 SMALL APPLIANCES WITH PLASTIC PARTS	PRODUCTS **CONTAINING AN APPRECIABLE AMOUNT OF PLASTICS** IN PAPER BOARD CARTONS ON WOOD PALLETS

DEFINITIONS

AVAILABLE HEIGHT FOR STORAGE	**MAXIMUM HEIGHT** AT WHICH COMMODITIES CAN BE STORED ABOVE THE FLOOR AND STILL MAINTAIN CLEARANCE STRUCTURAL MEMBERS AND SPRINKLERS
EXPOSURE	THE **EXTERIOR PRESENCE OF COMBUSTIBLES WHICH**, IF IGNITED, COULD CAUSE DAMAGE TO THE STORAGE BUILDING OR ITS CONTENTS
FIRE WALL	PREVENT THE SPREAD OF FIRE. HAVING A FIRE RESISTANCE RATING OF NOT **LESS THAN 4 HOURS**
HORIZONTAL CHANNEL	ANY **UNINTERRUPTED SPACE IN EXCESS OF 1524 M** IN LENGTH BETWEEN HORIZONTAL LAYERS OF STORED COMMODITIES
ORDINARY COMBUSTIBLES	HAVE HEATS OF COMBUSTION SIMILAR TO **WOOD, CLOTH OR PAPER** AND WHICH PRODUCE FIRES THAT CAN BE EXTINGUISHED BY THE **COOLING EFFECT OF WATER**.
EXTRA COMBUSTIBLE	**HIGHLY SUSCEPTIBLE TO IGNITION** AND WILL CONTRIBUTE TO THE **INTENSITY AND RAPID SPREAD OF FIRE.**
MODERATE COMBUSTIBLE	WILL CONTRIBUTE FUEL TO FIRE.
NON-COMBUSTIBLES	NOT IGNITE, BURN OR LIBERATE FLAMMABLE GASES WHEN HEATED TO A TEMPERATURE OF **745 C FOR FIVE MINUTES**.

LOCAL FIRE CODE (PD. NO. 1185)

- FIRE CODE OF THE PHILIPPINES

FIRE CLASSIFICATION

CLASS A	**ORDINARY COMBUSTIBLE MATERIALS** SUCH AS WOOD, CLOTH, PAPER, RUBBER AND PLASTICS
CLASS B	FIRE IN **FLAMMABLE LIQUIDS AND GASES**
CLASS C	FIRE INVOLVING **ENERGIZED ELECTRICAL EQUIPMENT**
CLASS D	FIRE INVOLVING **COMBUSTIBLE METALS**, SUCH AS MAGNESIUM, SODIUM, POTASSIUM, TITANIUM, AND OTHER SIMILAR METALS

DRY STAND PIPE	PIPES ARE NOT NORMALLY FILLED WITH WATER
FIRE SERVICE	**AN ORGANIZATION OF THE PHILIPPINE NATIONAL POLICE FIRE DEPARTMENT** PERSONNEL IN-CHARGE (MISSION: FIRE PROTECTION)
MEANS OF EGRESS	**A CONTINUOUS AND UNOBSTRUCTED ROUTE OF EXIT FROM ANY POINT IN A BUILDING**
OCCUPANT LOAD	THE MAXIMUM NUMBER OF PERSONS THAT MAY BE ALLOWED TO OCCUPY A PARTICULAR BUILDING

STORAGE CLASSIFICATIONS

TYPE 1	• STORED OVER **4,550 MM** BUT **NOT MORE THAN 6,400 MM** HIGH IN SOLID PILES • OVER **3,650 MM** BUT **NOT MORE THAN 6,400 MM** HIGH IN PILES **THAT CONTAIN HORIZONTAL CHANNELS**.
TYPE 2	• STORED **NOT OVER 4,500 MM** HIGH IN SOLD PILES • **NOT OVER 3,650 MM** HIGH IN PILES THAT CONTAIN **HORIZONTAL CHANNELS.**
TYPE 3	IS THAT IN WHICH THE STORED COMMODITIES ARE NONCOMBUSTIBLE OR CONTAIN ONLY A SMALL CONCENTRATION OF COMBUSTIBLES WHICH ARE **INCAPABLE OF PRODUCING A FIRE THAT WOULD CAUSE APPRECIABLE DAMAGE**

SPRINKLER SYSTEM - INTEGRATED SYSTEM OF ONE OR MORE WATER SUPPLIES FOR FIRE USE, UNDERGROUND AND OVERHEAD PIPING.

- **WET PIPE SYSTEM** – A SYSTEM EMPLOYING **AUTOMATIC** SPRINKLERS ATTACHED TO A PIPING SYSTEM CONTAINING WATER AND CONNECTED TO A WATER SUPPLY. MOSTLY USED IN OUR COUNTRY
- **DELUGE SYSTEM** – USING **OPEN SPRAY** HEADS ATTACHED TO A PIPING SYSTEM THAT IS CONNECTED TO A **WATER SUPPLY THROUGH A VALVE THAT IS OPENED BY MEANS OF A DETECTION SYSTEM INSTALLED IN THE SAME AREA AS THE SPRAY HEADS.**

HALON 131 (BROMOTROFLOURROMETHANE $CBrF_3$)

- COLORLESS, ODORLESS, ELECTRICALLY NON-CONDUCTIVE GAS. AN EFFECTIVE **MEDIUM FOR EXTINGUISHING FIRES**

ADDITIONAL NOTES:

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